

MANUAL
OF
DUROFUME PROCESS



CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE
MYSORE, INDIA



MANUAL OF DUROFUME PROCESS

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(Discipline of Infestation Control and Pesticides)
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PREFACE

The Durofume Process was developed at the Central Food Technological Research Institute by December 1957 and was exhibited at the India-1958 Exhibition. The requests from the industry, private agencies and the Government made it imperative to institute courses on the application of the Durofume Process on foodgrains, their products and many kinds of agricultural produce. Since 1958, Short-Courses are being conducted for the benefit of the personnel of the industry and government.

A "Manual of Durofume Process," which contained only the operational aspects was prepared in 1959 for Pest Control Operators. Since then the Professional members at Managerial and Advisory levels of organisations, advanced students and research workers in India and many foreign countries became increasingly interested in acquiring knowledge on the principles and practice of Durofume Process. The Second Edition, in addition to operational details contained research data on the fundamental and applied aspects of the process, which was brought out in January 1966.

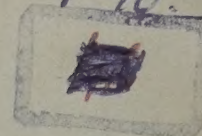
This new edition is virtually the same as the second edition published in 1966. It is envisaged that within a short-time a revised edition with the technological information on production and related manufacturing aspects of the Durofume fumigant mixtures in cylinder, in cans and in other containers and carriers will be brought out. Details of the pesticidal formulation for prophylactic treatments will also be included.

The encouragement of Dr. H.A.B. Parpia, our Director, and the help I received from Mr. T. S. Krishnamurthy, Mr. M. Muthu and Mr. M. Ramamurthy in the preparation of the Manual of the Durofume Process, are largely responsible for the emergence of this Manual.

I look forward to the suggestions from the readers of this Manual which could be incorporated in future editions.

May, 1967
Mysore-2.

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MANUAL OF DUROFUME PROCESS

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PRINCIPLES OF DUROFUME PROCESSDUROFUME PROCESS:

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Cereals, pulses, **spices** oilseeds, their processed products and dehydrated fruits and vegetables are attacked by insect pests during storage. Although, low moisture in dried products prevents fungal spoilage, all dehydrated animal and vegetable products are susceptible to insect-infestation. In India and tropical and sub-tropical countries insects breed at a fast rate and complete more number of life cycles in a year than those in temperate zones. In many parts of India the pests can breed throughout the year due to the climatic conditions. Damage done to stored commodities is of greater magnitude in the tropics than temperature areas.

Cereal grains and their processed products having granular shape are first attacked by the rice weevil, Calandra oryzae and subsequently other pests such as the red flour beetle, Tribolium castaneum and saw-toothed grain beetle, Oryzaephilus surinamensis, appear on them as secondary pests. The almond moth, Cadra cautella eats on the germ portion of the grain. The milled material with the mesh size below 18 is not normally attacked by C. oryzae. Whole flour is attacked by Cadra and spoilt considerably by webbing. Processed foods containing spices are infested by the spice beetle, Stegobium paniceum as the primary pest. C. oryzae and T. castaneum do not normally **attack** spices and seasoned (spiced) cereal products. Storage of these articles in the warehouses are done in different textile fabrics, laminated paper bags, and other flexible packaging films, which do not provide adequate barriers for infestation; migratory from outside sources.

The loss in storage due to insect infestation varies from 5 to 25 per cent in the cereals and their products during a storage period of 10 to 12 months in India. The pests not only consume but also render the foodgrains unhygienic due to the added filth resulting from their dead bodies, cast skins, excreta and foul odour. Large scale storage of bagged cereals, pulses, spices, oilseeds, milled and flaked cereals, macaroni products and coffee beans are carried out under warehouse conditions.

The insect problem in stored foodgrains should be tackled from two angles. First of all the insecticidal attack should be aimed at wiping out the existing or resident infestation. Secondly measures should be taken to safeguard against reinfestation either from the godown or from neighbouring or incoming material. Only this two-pronged drive will ensure enduring protection for stored grains. The "DUROFUME PROCESS" combines in it curative as well prophylactic treatments, viz., disinfestation and protection from further attack by insect pests.

Curative Treatment:

Coming to the first phase of the treatment, a suitable fumigant

has to be used which can do the job quickly and thoroughly irrespective of the nature of the commodity, bulk, infestation, etc. At the same time, the foodstuffs treated should be free of taint and harmful amounts of residue. Above all, the treatment should not be expensive.

Large amount of data have been collected on methyl bromide as a fumigant of bagged commodities at the Pest Infestation Laboratory, U.K., and other laboratories in U.S.A., Canada, France and Germany. Detailed studies, however, have not been carried out on the behaviour of methyl bromide under usual warehouse conditions with special reference to temperature effects. HCN, (Hydrogen cyanide), Phosphine, EDCT (ethylene dichloride and carbon tetrachloride mixtures are employed in India and elsewhere in the tropics without critical assessments of the relative merits with special reference to efficacy, safety, cost and self-sufficiency in a country. The common fumigants, singly and in combination were therefore, screened for their suitability for disinfection of stored raw and processed foodgrains in columns and silos and under gasproof sheets with bagged commodities in warehouses. The results have shown that it is hard to find any one fumigant which can satisfy the requirements demanded of even a near ideal fumigant. One has to fall back, therefore, upon a mixture of fumigants and count on their joint action to meet the requirements. In a programme of work carried out in 1957, while screening a variety of fumigants for their compatibility and joint action the value of a mixture of ethylene dibromide (EDB) and methyl bromide (MB) for practical disinfection of commodities was immediately recognised. Stratification of the fumigant mixture in high grain bag columns gave adequate concentration throughout the grain bulk and exerted toxic action over all the stages of pests lying in all layers of the grain bag stack. Not only was the mixture highly toxic to the insects, but it did not also leave high residues in grain. Poor penetrating properties of ethylene dibromide was repeatedly recognised during commercial fumigation work especially when fumigating highly infested grain with a high dockage as also in stacks of more than 6 feet in height. Methyl bromide on the other hand has given good results as a fumigant in air-tight chambers and perfectly hermetic warehouses. The degree of air-tightness required for a fumigation with MB at temperatures higher than 23°C is quite difficult to achieve under commercial conditions. Rapid escape of the gas from inside gas-proof sheets is noticed; within a few hours the fumigant concentration inside the stack becomes inadequate for proper disinfection. It is also known to leave residues especially in protein-rich materials. Another common feature with MB is that it sinks too rapidly to the bottom and often leaves the top layers of stacks under-dosed under the temperature conditions above 23°C. The insects near the top layers often survive even after fumigation with MB. Having no perceptible odour is another draw back, though addition of 2% chloropicrin is sought to eliminate this draw back. How far this enables one to detect the gas in low, but dangerous concentrations is not clearly known. When applied at 24-30°C, it has been noted that chloropicrin is retained in the cylinder and near the nozzle because of the cooling that takes place at the nozzle of the cylinder and methyl bromide flows through the tube in gaseous state while chloropicrin is retained in the tubing. At the level at which it

is usually mixed with methyl bromide it has proved to be inadequate for serving as a warning agent under the conditions of use in India. Only halide detectors have been found to reduce operational hazards when methyl bromide is used alone. Ethylene dibromide when used alone with methyl bromide has been found to increase the safety factor. At present ethylene dichloride - carbon tetrachloride mixture (EDCT), methyl bromide and other fumigants are imported. The combination of ethylene dibromide and methyl bromide when used on an all-India scale, will reduce foreign exchange requirements to a minimum on the account of fumigant import. Ethylene dibromide, the cheapest of the brominated hydrocarbons is being manufactured in India.

Phosphine has been used in recent years as a fumigant. The formulation consists of aluminium phosphide and ammonium carbamate. This is manufactured only in Germany and no other country of the world. If grain contains moisture less than 12%, it does not generate phosphine fully from the tablet even within 6 days. Moreover, many pests can survive high doses of phosphine. Rice weevil, spice beetle, coffee bean weevil and many others are resistant to phosphine.

Table I: Resistance of some insects and their stages to common fumigants.

	'Sito- philus	Trogo- derma	'Calloso- bruchus	'Stego- bium	'Araece- rus
	E L P A	E L P A	E L P A	E L P A	E L P A
Ethylene dichloride and carbon tetra chloride	+ + + -	+ + + +	+ + + -	+ + + -	+ + + -
Phosphine tablet	+ + + +	+ + + -	+ + + +	+ + + +	+ + + +
Ethylene dibromide	- - - -	- - - -	- - - -	- - - -	- - - -
Methyl bromide	- - - -	- - - -	- - - -	- - - -	- - - -
Carbon disulphide	- + + -	+ + + -	- - + -	- - + -	- - - -
Chloropicrin	- - - -	- - - -	- - - -	- - - -	- - - -

+ Not killed (resistant) at normal doses at 25°C' E = Egg, L=Larva
 - Killed (susceptible) at normal doses at 25°C '
 ' P = Pupa, A=Adult

The studies showed that out of the fumigants tried methyl bromide and ethylene dibromide combinations were the best for practical disinfestation in loaded silos and warehouses.

Studies were therefore, carried out with reference to the behaviour of ethylene dibromide and methylbromide under different

temperature conditions and data on the distribution of the fumigants in bagged commodities and their effect on the stored grain pests were collected. Detailed procedure for practical application, differential composition of gas samples from different positions of grain and semolina in silos and columns and the distribution of fumigant residues were studied.

Mode of application under warehouse conditions:

Commercial scale trials were carried out with EDB and MB combination and the methods of application were standardised. The usual metal cylinders were evacuated and the required volumes of ethylene dibromide and methyl bromide transferred. In cases of higher proportions of methyl bromide in combinations other than 1:1 (EDB:MB, w/w), cooling of the evacuated cylinder while filling the gas was found advantageous. An applicator has been designed for applying ethylene dibromide and methyl bromide in different proportions.

The application on bag stacks under gas-proof sheet is carried out by a system of tubings as practised for methyl bromide fumigation. Instead of spray nozzles at the exit points the film vaporisers as developed by the Institute were used, and in place of usual gas masks with canisters, air-hose of non-kinking and non-collapsible type was connected to the face piece. Remote control lifting of the gas-proof sheet for airing the fumigated stack at the end of exposure period is accomplished with the help of ropes and pulleys. These are found to reduce the cost of fumigation treatment considerably, on account of least use of gas-mask canisters. A process has also been developed for reviving exhausted gas-mask canisters. Foreign exchange can be saved on the import of gas-mask canisters.

Durofume fumigation can be carried out in a terraced godown which can be made airtight. Good gas-proof sheets of rubberised cloth or PVC-coated fabric can also be used for fumigation with Durofume fumigant combination. Tents that are now being used for EDCT fumigation can be safely used. An EDB-MB applicator, has been designed for applying different proportions of the fumigants from cylinders or cans. Pressurised packaging of EDB and MB in a single cylinder has also been achieved. The single pack and the DUROFUME APPLICATOR have proved to be not only safe but easy in applications. At present these are supplied by the Institute to trained pest control operators.

The aeration is quicker than with EDB fumigation. The characteristic odour of EDB is another advantage since it serves to warn against undue exposure in addition to the lachrymatory action of chloropicrin. Gas-masks, however, have to be worn by the operators to ensure safety. It has been observed that the gas-masks can serve for a longer period when used with the Durofume combination than with EDCT or MB due to the high affinity of the gas-mask adsorbents for EDB in addition to the other gases already being adsorbed. Investigation regarding reconditioning of old canisters and their service times with different fumigants and their mixtures have been completed. Air-hose type gas-mask has also been designed. The

remote control device for lifting the gas-proof tent after the exposure period can be used ensuring safety and the added advantage of economising on the expenditure on canisters.

Gas concentrations and distribution at the end of different exposure periods can also be checked by a gas-analysis kit developed at the Institute which is based on the reaction at room temperature of Durofume with monoethano-lamine. A simple and quick bioassay technique has been developed which enables the operator to know the success of fumigation even before completion of the fumigation.

Toxicity towards insects:

The 'Durofume' fumigant is highly effective against the pre-adult as well as adult stages of even resistant species like Tribolium castaneum and Trogoderma granarium. All proportions of the mixture are more toxic than either of the fumigants used alone. Samples drawn after fumigation have remained insect-free after the incubation period under accelerated conditions.

Residues:

The residues estimated as total bromide have always showed unexpectedly low values and were less than those obtained in products fumigated with either of the fumigants at their effective dosages. Data collected on the residues of Durofume on various commodities have shown that they are far below the residues normally obtained for EDB or MB used as single fumigants.

Proportions and Dosages:

Cereals, pulses and spices:- A 1:1 mixture at the rate of 1-2 lb. per 1000 cubic feet is recommended. An exposure period of 48 hours should be generally adopted. If the temperature is more than 26°C, 36 hours exposure has been found to be enough for disinfesting grains. At temperatures below 18°C, 1:3 mixture of EDB:MB is to be applied.

Oil-seeds:- A 1:2 mixture of EDB:MB at 1.5-2 lb/1000 cu.ft. is suitable for disinfesting oilseeds. An exposure period of 36-48 hrs. is required.

Milled cereals:- A dosage of 2-3 lb (1:3 mixture EDB:MB) per 1000 cu.ft. of material with an exposure of 48-72 hours is recommended depending on the nature of the fumigation chamber, godown and heavy gas-proof cover.

Results of the experiments carried out at the Institute have indicated the following:

i) Incorporation of EDB in MB improved its insecticidal effect and helped in maintaining more uniform concentrations at all layers of the commodity under fumigation;

ii) At 100°F and above beneficial effects of EDB-MB combinations are very conspicuous both in the fumigation trials carried out in silos and gas-proof sheets;

iii) Permanent residues in the foodstuffs are comparatively less with the mixture than methyl bromide alone;

iv) Operational safety is greater with the mixture than MB alone with 2% chloropicrin, as EDB can carry both MB and chloropicrin in dissolved state to the exit points.

At temperatures above 35°C, dosages for DUROFUME should be reduced and proportions of ethylene dibromide should be increased.

Prophylactic treatment:

Fumigation is a curative process. For insect free storage of foodstuffs under warehouse conditions the disinfection process should be accompanied by a prophylactic treatment to prevent reinfestation in the fumigated stack. In a godown the movement of commodities is common. New stacks are built and old stacks are broken for release. Infested materials become the sources for further contaminations and infestations. To ensure permanent prophylaxis against insect the fumigation process also should be able to kill all the life stages (egg, larva, pupa and adult) present in all the layers of the bulk commodity in addition to the prevention of cross-infestation by an insect proof barrier.

Screening of the commonly available fabrics and plastic films used for bagging of cereals and their processed foods have shown that either one or all the pests such as C.oryzae, S.paniceum, A.fasciculatus, B.chinensis, Rhizopertha dominica, Periplaneta americana, Cadra cautella and Corcyra cephalonica were able to penetrate through the packaging materials or lay eggs inside the bags.

At the CFTRI studies carried out showed that insect-proofed jute and other textile bags could be obtained by spraying with O/w type emulsion with a machine containing low volume spray nozzles and having regulated conveyor feeding arrangement for spraying empty bags. As compared to 1.8 kg., the usual water uptake of a standard B-twill bag from an emulsion bath, only 20 gms. of water were taken up by 16-18 sq.ft. surface of bags in the latter process. Drying of the spray treated bag with the formulation containing DDT and Lindane in the water dispersible formulation was not difficult even in large scale production. The insect-proof bags can be used for storing grains. Milled materials cannot be stored in these bags.

Most often insecticidal treatment of bagged foodstuffs are required during storage in the warehouses of processed food factories. It is difficult to spray the interior of the loaded warehouse with water dispersible composition in view of moisture increase and fungal growth. Dusting with residual insecticidal formulations also cannot be carried out as it presents food contamination hazards. A study was

therefore taken up to develop a dry process for a prophylactic spray treatment of the stacks of bagged commodities in situ, with a view to applying it in conjunction with the fumigation treatment.

The most commonly used process in India for disinfection comprises of fumigating the foodgrain bags with a dosage of 25-35 lb. of EDCT mixture per 1000 cu.ft. and routine dusting of the bag stack with 5-10% BHC formulation at intervals of 15-21 days. BHC contains in it in addition to the gamma-isomer other components which are not insecticidal but possess chronic toxicity hazard for humans. Infiltration of the residual BHC dust into the grain from the surface of the bags occurs inevitably during repeated applications. By this process the contamination with BHC dust gives rise to cumulative increase on grains, it is therefore necessary to avoid application of dust formulations and also accumulation of other isomers of BHC than the gamma isomer (Lindane). Very often for good foodgrain storage, fumigation with EDCT should be repeated at 3 month-intervals.

Malathion has largely replaced BHC dusts in grain warehouses. Since water based formulations such as wettable powder and emulsions are used the stability of malathion is very low, every 2-3 weeks spraying has to be repeated. It is peremptory that the fumigation process should be able to kill all life stages (egg, larva, pupa and adult) of the pests present in all the layers of the bulk commodity to ensure permanent prophylaxis. Durofume fumigant combination has been found to be the cheapest and most efficient in disinfecting foodgrains, oilseeds, oilseed cakes, milled products, coffee, dry fruits, macaroni products, and many other commodities.

The prevention of reinfestation (cross-infestation) has been achieved by careful selection of solvents, synergists and pesticides and by adjustments in application of the formulation on the outer surface (periphery) of the stack. Compositions and viscosities of formulations vary according to the sacking materials and commodities stored. Fabrics in gunny bags are A-twill, B-twill, Heavy cees, D.W. or Hessian types. A-twill and B-twill sacking materials have smaller pores (weave clearances) and permit direct spraying of a high viscosity oil-based lindane formulation without the risk of contaminating the grain stored in them. The formulation (DUROBASE-1) is sprayed through a low volume nozzle at 30-35 lb./sq.in. pressure at the rate of 2 to 2.5 ml. per square foot of the bag stack surface. 50 mg. of lindane sprayed per sq. ft. in the oil based formulation, DUROBASE-1, containing a mixture of Dutra-3, Batching oil, Linseed oil, Groundnut oil as the carrier, have been found to exert prophylactic action for a period of 4-5 months. Repeated spraying of DUROBASE-1 at 3 month intervals is enough to keep up the residual action on the fabric surface for preventing cross infestation. Studies on the assessment of contamination of foodgrains by the droplets infiltrating through the web clearance or other routes by application of this technique have shown safety in this respect. The problem was further investigated for storage of grain bags in insect-free condition for periodical release from the treated stack. A formulation based on lindane and malathion should be sprayed from time to time on the wall and around the stacks.

If the issue of bags is done from the remotest column of the stack and is followed up by spraying with the lindane-malathion oil-based formulation on the exposed surface, it yields excellent result. No liberal spraying is necessary. The sprayed surface should appear dry after spraying. Even a prophylactic spray with pyrethrin and piperonyl butoxide in an oil base, if repeated from time to time as and when new stacks are erected or stacks are disturbed, will give some protection from cross-infestation. The main drawback of thin volatile mineral oil based formulation is the contamination to grains. While spraying it gets atomised to very fine particles and are drifted into the commodities through the weave clearance of bags. Moreover, the particle size of droplets being very low the insecticide volatilize very rapidly. The spray loses the effectiveness within a few days.

The mineral oils which are thin are absorbed rapidly by grains and also constitute consumer's hazard. Most often it exceeds the permissible limit of 200 ppm. It is for this reason non-volatile high viscosity oil should be used in preference to thin oil formulation under warehouse conditions.

In the case of bags having high weave clearances such as the D.W. and Hessian types, direct spraying on the grain bag surface is not desirable. Sacks meant for storage of milled materials also should not be directly sprayed with the insecticidal formulations. Small particles of milled commodities ooze out of the web clearances and get contaminated and also form a layer over the insecticidal films on the surface of bags. In such cases treated gunny cloth is spread over the bag stack to prevent cross-infestation. Excellent results have been obtained with DUROBASE-2 treated prophylactic cloth especially in controlling *Ebhestia* sp. on foodgrains and milled products. DUROBASE-2 formulation containing DDT and BHC should be sprayed on a gunny sheet (prepared by stitching old gunny bags together) at the rate of 2-2.5 ml. per sq.ft.

The impregnation of the gunny cloth has also been done with the lindane-dieldrin based formulation but due to the non-availability of dieldrin, its physico-chemical properties of being sorbed through the skin, its toxicity to man and relative volatility in comparison to DDT, a careful and restricted application is desired. Extensive use of this formulation is being made with excellent results for termiteproofing (control of white ants) of structures. Under specified conditions of use no hazard is associated from the operational as well as consumers' points of view. However, DUROBASE-2 based on DDT and BHC has proved advantageous under the conditions of use. DUROBASE-2 when sprayed on gunny cloth remains effective in controlling pests for a period of 10-12 months. Both the pesticides are produced in India and many countries in the tropics.

A new composition has been developed which in addition to its insecticidal action can repel rats. DDT, Lindane and Malathion carried in non-volatile high viscosity oils have been found to give rat repellent action in addition to insecticidal effects on grain bag stacks. This formulation is sold under the name DUROBASE-3 which is finding extensive application for insect and rodent control in storages.

Conclusions:

1. The results of laboratory and commercial scale trials have repeatedly proved the superiority of the EDB and MB mixtures, over all other fumigants tried so far in the country under all possible conditions and therefore show promise for application in the grain conservation programme of the country.

2. Prophylactic treatment is an essential step for preventing cross-infestation of the fumigated stocks. The fumigation treatment when accompanied by a prophylactic spray treatment can ensure insect free condition of the commodity for longer duration.

3. High viscosity and non-volatile oils remarkably increase the persistence and insecticidal potency of all the insecticides tested as compared to low viscosity oils, and water dispersible formulations. Use of the insecticide treated cloth over the fumigated stack for preventing cross-infestation is found to be very safe, effective and practical.

These results of the investigations could be extended to bagged commodities under warehouse conditions and also small packages in retailers' shops. The process being cheap, efficient and safe several firms have been applying the Durofume process in India for contract disinfection servicing in private and government warehouses with excellent results. Wide ranges of commodities can easily be treated under varied conditions by adjusting the proportions of EDB and MB according to the chemical composition of the products, package size and material, warehouse conditions and atmospheric temperature.

A critical appraisal:

The existing methods of disinfection in many Departments, who carry out disinfection treatments only departmentally, employ imported fumigants such as, phostoxin (phosphine generating tablet), EDCT mixture (ethylene dichloride and carbon tetrachloride) and to some extent methyl bromide (MB). In recent years EDCT and MB have largely been replaced by phostoxin. The phostoxin tablets, possess inherent toxicity and operational problems which have not been critically examined. Excepting Germany no country can manufacture this product. Non-availability of special gasmask canister and detectors sensitive to 0.05 ppm, the permissible concentration, toxicity to man is 500 times more with phosphine as compared to methyl bromide and these are the greatest drawbacks. Contract disinfection is not possible with this tablet as time required is about 6 days and grain moisture should be atleast 12% for the use of the Phostoxin tablets. Many major pests are highly tolerant to this fumigant inspite of its extreme toxicity to mammals. Phostoxin is more suitable for outdoor disinfection such as Railway wagons, silos fitted with mechanical handling of grains etc. Comparative data on the physico-chemical and toxicological characteristics on the candidate fumigants are given in the Table 2 which will reveal some of the basic considerations necessary for the choice of a tropical fumigant.

Table II: Comparative physico-chemical data on prospective fumigants (Part I)

Fumigant	M.W.	m.p. 0°C	b.p. 0°C	Latent heat of vaporization (Cal/g.)	v.p. at 25°C mm. Hg.	Specific gravity gas (air=1)
1. Hydrocyanic acid	27	-14	26	210	739	0.94
2. Methyl bromide	95	-98	3.6	61.5	1824	3.27
3. Phosphine	34	-133	-87	102.6	30000	1.52
4. Sulphur dioxide	64	-73	-10	64	2809	1.43
5. EDB + MB (1:1)					1277*	
6. EDB + MB (1:2)					1500*	
7. EDB + MB (1:3)					1618*	
8. Acrylonitrile	53	-83	-77	-	107	1.83
9. Carbon disulfide	76	-112	46	84	361	2.63
10. Carbon tetrachloride	154	-23	77	46	114	5.31
11. Chloropicrin	164	-64	112	-	24	1.65
12. Ethylene dibromide	188	10	132	46	12	6.4
13. Ethylene dichloride	99	-35	84	85	80	3.5
14. Ethylene oxide	44	-111	11	139	1240	1.5

* at 30°C

Part II

	Flammability in air Vol. %	Amount reqd. to sat. 25°C (mg./L)	LD50 T.cast. (mg./L)	Max. permissible concn. (ppm)	Odour threshold (ppm)	Detection (within safe limit)	Behaviour under gas-proof sheet above 25°C (leakage)
1. Hydrocyanic acid	6	1072	0.6	10	5	No	Heavy
2. Methyl bromide	13.5	3874	11	20	None	Yes	Heavy
3. Phosphine	1.7	1387	2	0.05	3	No.	Heavy
4. Sulphur dioxide	-	2614	6	10	5	Yes	Heavy
5. EMB + MB (1:1)	Non-inflam.	-	1.4	25	20	Yes	Slow
6. EDB + MB (1:2)	Non-inflam.	-	2.1	25	20	Yes	Slow
7. EDB + MB (1:3)	Non-inflam.	-	3.6	20-25	20	Yes	Moderate
8. Acrylonitrile	3	319	-	20	35	No	Low
9. Carbon disulfide	1	1430	61	20	60	No	Slow
10. Carbon tetrachloride	Non-inflam.	916	185	25	70	Yes	Slow
11. Chloropicrin	Non-inflam.	220	3.1	0.1	Very low	Yes	Low
12. Ethylene dibromide	Non-inflam.	141	14	25	20	Yes	Low
13. Ethylene dichloride	6	430	19	100	50	No	Low
14. Ethylene oxide	3	1800	18	50	-	No	Heavy

The other treatment of the stocks relate to prophylactic aspect which is directed to prevent the entry of insects from outside sources. For such treatments BHC, pyrethrin, lindane and malathion either in dust or in water dispersible formulations are used for application on grain bag stacks. The treatment is applied every 3 weeks resulting in progressive contamination to foodgrains and high cost.

The organisations such as Coffee Board, some of the State Civil supply Departments, grain merchants, cooperative societies and exporters who require quick, efficient, economical and safe disinfestation treatments which are to be carried out by commercial agencies on competitive basis, invariably accept Durofume process developed by the CFTRI. The Ministry of Defence have already gone through the scientific, technological, medical and related aspects of the process very critically and accepted the application of Durofume process in the foodgrain stocks maintained by them. It is now desirable to apply Durofume process on a competitive basis in the stocks held by Governments, Corporations and related bodies because of the definite advantages for climates like India under largescale storage conditions.

Investigations at the CFTRI have shown that the behaviour of fumigants like methyl bromide and phosphine are quite different under temperate climatic conditions as compared to the tropical climate. The Warehousing and conditions of storage are also quite different. In a tropical country like India, the fumigants, which are found effective in the temperate conditions, offer many operational difficulties in their applications due to the modifications of properties at high temperatures. Since most of the infestations in grains in India occur during the hot seasons in most of the areas and also throughout the year in areas where temperature below 15°C is not encountered, critical studies on the efficacy and suitability of fumigants from scientific, economic and technological angles in the perspective of India, were carried out. Fundamental studies on the behaviour of ethylene dibromide (EDB), methyl bromide (MB), EDCT mixtures and mixtures of EDB and MB have shown that combinations of EDB and MB at different proportions behave better than MB or phosphine or EDCT mixture from the point of view of efficiency against insect at low dosages distribution and penetrability within the bag stack, retention within the fumigation cover and in non-airtight godowns, operational and consumer's safety, etc. A process for largescale application under commercial conditions known as "Durofume Process" has been developed. The process combines in it along with disinfestation by a fumigant mixture containing ethylene dibromide, methyl bromide and chloropicrin, a prophylactic treatment of the bag stack with a formulation of high viscosity vegetable and mineral oils containing lindane and DDT as active ingredients. Thorough, painstaking and original studies at the CFTRI have led to the development of the above process. Further improvement in the Process has been brought about by making the spray composition (Durobase) also rodent repellent. This high viscosity oil based formulation is superior to dust and water dispersible formulations and safer and cheaper for storage of foodgrains.

Behaviour of fumigants in combinations have been studied thoroughly in laboratory and commercial scale. New properties of ethylene dibromide-

methyl bromide fumigant systems have been discovered and advantages with respect to action on insects, degree of reaction with food components, joint action and synergism at tropical and temperate temperatures have been demonstrated. Large scale production techniques, safe handling methods, indigenous kits and appliances have been developed. Already 2-3 million tonnes of foodgrains have been successfully treated by commercial firms. Introduction of the Durofume Process by the Coffee Board for storage of coffee has revived a dwindling export market of monsooned coffee. Increase in foreign exchange earning in this coffee alone had been Rs.20 lakhs annually. For the last five years the Coffee Board have extended the application of Durofume Process with great benefit even on plantation and other grades of coffee. Cashew Export Promotion Council, Spices Export Promotion Council, Grain Merchant's Associations, Cooperative Societies, Exporters, Spice Merchants, some State Governments have been utilising the services of firms who have been applying the Durofume Process.

The most striking feature of Durofume Process, in addition to its ability to kill all stages of existing infestation, is its efficiency against reinfestation of insects and also protecting against rats by exerting repellent action. The Durofume Process developed by the Institute is the cheapest, most efficient and safest of all the existing processes for insect and rat control. First time in the world a successful prophylactic spray composition has been developed for long term protection against insect infestation and also rat damage by spraying on stack. The process has been applied with excellent results in existing private godowns which are far from ideal in construction.

Augmentation of food resources, reduction of the foreign exchange requirement on fumigants and pesticides import and increase of the export trade, are the beneficial results of the extensive application of Durofume Process on foodgrains, oilseeds, spices and their products. A vast industry is developing in India rapidly utilising the Durofume Process. Results on the various studies have been published in many international journals by the research workers of the CFTRI.

No import of any other fumigant will be necessary if EDB-MB mixtures are applied by the CFTRI Process. Even if the entire quantity of this fumigant is imported the cost of import will be the lowest on the basis of quantity of grains treated in the country. Ethylene dibromide plants have already been set up in India while the production of methyl bromide will be started if adequate market for the product could be established even in the Government establishments handling grains. In fact every kilogramme of Durofume used saves at least Rs.1,000/- for India as foodgrain.

Table III gives the comparative merits of the prospective fumigants.

Table III - Comparative merits of prospective fumigants.

Insecticide	Cost for 20 tonnes one year	Suitability for treatment	Possibility of indigenous production	Operational safety (Permissible limit)
1	2	3	4	5
EDCT(Ethylene chloride and carbon tetrachloride mixture)	@ 35 lbs/1000 cft. x 4 Rs 130/-	Not an efficient fumigant for insect kill. Soaks grain with large volume of ethylene dichloride and carbon tetrachloride as solvents. Not suitable for fumigation of milled materials and oilseeds. At least 4 fumigations required per year. Cost too high and require long exposure time.	Yes	Toxicity has been overlooked. Too costly on gas mask canisters (20 ppm permissible limit)
Phosphine (Phostoxin)	@ 1 tab./Ton x 4 Rs.20/- Recommended dosage is at least 3 times more. Therefore normal cost is Rs.60/-	Excepting commercial firm's data, very little toxicological, pharmacological laboratory data available. Not suitable for indoor fumigation and milled stuff in bulk. Very slow process, requires 6 days. Cannot give total control on some major pests i.e., Rice weevil and Coffee Bean weevil at even several times the recommended doses. Disposal of tablet difficult in bulk treatment. Grain containing moisture less than 12% should not be fumigated with phostoxin which limits its appln. greatly.	No possibility for production in India. High cost of foreign exchange. Only manufactured in Germany & no other country of the world due to extreme hazards.	1. Extremely toxic. 2. Special gas mask required is not manufactured in India, and cost too high. 3. Detection within safe limit not possible (0.05ppm) 500 times more toxic than EDB & MB to man 4. Affects bone.

Table III (Contd.)

1	2	3	4	5
EDB + MB as mixture	@ 0.75-1.5 lbs./ 1000 cft. x 1 Rs 4/- to 7/-	Full scientific data on all aspects are available in extensive published literature. Cheapest, only one fumigation required per year. The process is very quick, requiring about 36 hours. All materials can be treated even oilseeds, milled materials, cereals, etc.	Indigenous production will be self-sufficient	Extremely safe due to incorporation of EDB and application by CFTRI Process under the climatic conditions presented by the country particularly when disinfection is needed. Permissible limit 25 ppm. Possesses warning odour and detection is easy
Methyl bromide	@ 1.5-2 lbs./1000 cft. x 3 Rs 30/- to 36/-	Scientific information fully available. Suitable for efficient use at temp. below 15°C. At higher temperature airtight chambers are needed and mechanical aid for uniform distribution essential. Unsuitable for fumigation under godown conditions in India particularly at temp. over 20°C due to quick stratification and leakage. At least 3 fumigations reqd. annually. Needs tropicalisation by adding a low vapour pressure compatible fumigant with it and lowering of its dosage. Reaction with food is very high at hot weathers resulting in high residues.	Yes	Unsafe as a single fumigant. No warning odour is discernible due to separation of chloropicrin from Methyl bromide at tropical temperatures. Permissible limit: 20 ppm. Requires tropicalisation for safe application at temp. above 20°C.

The CFTRI, Mysore have been conducting courses for training pest control personnel on the application of "Durofume Process".

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BASIC STUDIES:

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USING ETHYLENE DIBROMIDE WITH METHYL BROMIDE FOR GRAIN DISINFESTATION

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ETHYLENE DIBROMIDE has found enormous application in disinfecting fruits, vegetables, foodgrains, seed beds, mills and warehouses in all the advanced countries of the world. Under the Food Laws of USA, Canada and continental countries, the permissible residue limits for the fumigant have been fixed. The fumigant due to its high boiling point, can be used as a spot fumigant where only small bulk has to be penetrated in continental and cold climate. Recent trend of its use for mill or factory space, silo and warehouse fumigations, is in combination with other fumigants, such as carbon tetrachloride, carbon disulphide, ethylene dichloride, methyl bromide, etc. In India, the climatic and other factors make ethylene dibromide, either singly or in combination with other fumigants, more suitable, cheap and efficient for use than the fumigants in general use to-day.

Several factors affecting the fumigation of food commodities for insect control with chemicals, should be considered for recommending their large-scale application. The principles governing the application of ethylene dibromide as a foodgrain fumigant in India and other tropical countries are described under the following heads:

- I. Physico-chemical properties
- II. Laboratory investigation on the 'Use as a fumigant'
- III. Insect control trials in warehouses in India and elsewhere.
- IV. Operational hazards
- V. Significance of residues in foodstuffs-Ethylene dibromide, methyl bromide
- VI. Conclusions.

1-2

I. Physico-Chemical Properties

1,2-Dibromoethane or Ethylene dibromide, $\text{CH}_2\text{Br}.\text{CH}_2\text{Br}$. has a boiling point of 131.5°C at 760 mm, molecular weight 187.86, sp.gr. 2.182 at $20^\circ/4^\circ$, melting point 9.3°C , vapour tension 11 mm at 25°C , specific heat at 21.3°C , 0.173 cal/g heat of vaporisation at 130.5°C , 46.24 Cal/gr and dielectric constant at 20.5°C (10^5 cycles/sec.) 4.77. It is a clear and colourless liquid with a characteristic chloroform-like odour and is miscible with carbon tetra-chloride, benzene, gasoline, ether and anhydrous alcohols at 25°C . In water, the solubility is 0.40 g per 100 g at 20°C .

II. Laboratory trials on the use as a fumigant.

Neifert Et al. (1925)³ determined the minimal lethal concentration of ethylene dibromide for Sitophilus oryza (L),

S.granarius (L) and Tribolium confusum (Duv). They recommended further experiments with the compound. Roark et al. (1929)³ using ethylene dibromide obtained its lethal concentration against S.oryzae in loaded laboratory fumatorium. In palestine, Plaut et.al⁵ studied the penetrating power and toxicity of ethylene dibromide. Aman, Farkas, Benshamai and Plaut (1946)⁶ made comprehensive studies on the fumigant and reported about commercial success with grain and seed stocks. In Canada and USA, ethylene dibromide has been extensively used as a fumigant and the tolerances for the residues on grains have been prescribed.⁷⁻⁸ In combination with other fumigants such as carbon tetrachloride, carbon disulphide, etc., at various proportions, ethylene dibromide has been in use even in temperate countries. In these combinations, however, the quantity of ethylene dibromide applied on grain is almost equal to that of ethylene dibromide when used as a single fumigant. Muthu and Pingale⁹ have studied ethylene dibromide as a spot fumigant in disinfecting grain in individual gunny bags. Later, the warehouse trials carried out in India, revealed that, ethylene dibromide was suitable for routine disinfestation of warehouses. Its high sorptive properties, however, resulted in low penetrating ability of ethylene dibromide in grain bulk. Majumder and Muthu¹⁰ therefore, studied various combinations of fumigants with ethylene dibromide and found that ethylene dibromide in combination with methyl bromide brought about the best properties of both, and the joint action gave the properties nearest to an ideal fumigant.¹⁰⁻¹² Data on the fungicidal and fungistatic properties of ethylene dibromide have also been collected by Majumder et.al. at the Central Food Technological Research Institute,¹²⁻¹⁶ At temperatures of 35°C and above, ethylene dibromide acted as fungicidal agent, while at lower temperature, acted as a fungistatic chemical.

III Insect control trials with ethylene dibromide in warehouses:

Aman et al.⁶ found that the fumigant was to be distributed in such a way that the distance between the various points of introduction did not exceed one meter in the grain bulk. The fumigant was poured into the pipes properly distributed and in this way, the thickness of the layer through which fumigant had to diffuse was limited to half a meter. The results were excellent with reference to insect control. Other experiments carried out outside Palestine, have shown that when a fan is used, the exposure period for grain kept in sacks may be reduced to 24 hours for a concentration of 75 g/m³ (4.5 lbs/g 1000 c.ft.).

Besides the controlled fumigations, routine fumigation with ethylene dibromide were carried out throughout Palestine during the year 1943-45. More than 30,000 m³ of store room were fumigated during this period. The concentrations used varied from 50 to 100 g/m³ (3 to 6 lbs/1,000 c.ft) with 5-10 days of exposure.

From the work carried out by Aman et.al. the following conclusions could be drawn. Ethylene dibromide vapours are highly toxic to C.oryzae and Tribolium sp. and a dosage of 3-6 pounds of ethyl dibromide per 1,000 c.ft of foods to be fumigated was

necessary. It however, does not penetrate very far into the material being fumigated. It is absolutely non-flammable, and electrically-driven fans can therefore be used safely within the store rooms to facilitate evaporation, distribution and penetration.

Experiments have shown that in empty experimental stores, a concentration of 15 g EDB per m³ and an exposure of 24 hours were sufficient for a 100% kill of Calendra oryza and Tribolium sp. compared with a concentration of 150 g/m³ required when EDCT is used.⁶ EDB has been found suitable for fumigation of grain in larger mechanised silos. In this case, the fumigant should be introduced continuously with the stream of grains as is done in the case of chloropicrin.

EDB, when used at the rate of 10 cc/bag of 200 lbs of grain completely controlled the insects.⁹ In bags arranged in stacks, 7.5ml/bag was found sufficient to get a complete mortality of insects. EDB was injected into the bags individually and stocked under non-air-tight condition. The residues in jowar were of the order of 12-13 ppm as inorganic bromide and dosage applied amounts to 120 mg/L (about 7 lbs/1,000 c.ft.).

Large-scale trials carried out by the Central Food Technological Research Institute, Mysore. Investigations carried out by at this Laboratory have shown that routine disinfection with EDB can be carried out at about $\frac{1}{2}$ of the cost of EDCT (Ethylene dichloride-carbon tetra-chloride mixture) fumigation treatment. In parts of India where insect infestations warrant the disinfection treatment, the usual temperature of the atmosphere will not be very low and range between 23-41°C. During the months of March-October, disinfection treatments are required in most parts of the country. During these months, EDB can be handled without any difficulty. In other words, during winter months, disinfection treatments are not required in some parts of India. But, in the parts of India where winter months do not have low temperatures, such as the Deccan Plateau, insects breed throughout the year, and disinfection with EDB can be carried out in the commodities all the year round. In large stacks, refumigation of stored grains after an interval of 3 months, are needed. It is normally found that 60-80% mortality of insect pests are obtained with EDB and also by EDCT in commercial stacks of cereals. The technique of application has a great bearing on the success of fumigation with EDB. If proper distribution is effected in all layers of bag stack, it behaves as a very effective fumigant. At 3-4 lb dosage of EDB per 1,000 c.ft or 200 bags of grain and an exposure period of 6 days similar effect of EDCT fumigation can easily be obtained at temperature above 23°C under warehouse conditions.

To make EDB more efficient in disinfecting foodgrains, pulses and spices, 25% to 50% addition of MB(methyl bromide) in fumigant formulation has been found to be extremely helpful.¹¹⁻¹³ By incorporation of 25% MB in EDB, it is found to be effective even at 2 lb/1,000 c.ft. dosage and 48 hours to 60 hours exposure period. With this combination, 100% mortality of pests are obtained at all layers of grain bag stack. A mixture (1:1) of EDB:MB at 1.5 lb/1,000 C.ft can give 100% mortality of all pests in grain bag stack of commercial size. Best

TABLE A

Fumigant concentration in 5' column of sorghum 32 mg/litre dosage, 78°F.

Fumigant % w/w		Integrated concentration -Time product, 48 hours exposure, --- mg hour litre	
EDB	MB	Top	Bottom
100	0	372	48
75	25	422	96
50	50	656	298
0	100	739	169

properties of both ethylene dibromide and methyl bromide can be brought about by the combination under Indian conditions.^{13,17,23} Even a very small proportion of EDB in MB reduces the handling hazards considerably. The combinations of EDB and MB can be used within wide range of temperatures, on any sized stack, and can be applied with safety on foodgrains, pulses, spices, oil-seeds, oil-seed cakes, coffee, atta, flour, soji and dry fruits. Commercial trials have been carried out at this Institute on the application of Ethylene dibromide and EDB-MB mixtures under Indian conditions for disinfection of foodgrains.

Commodities like wheat, rice, jowar, pulses, spices, copra, oil-seed cakes, groundnut, macaroni products, coffee beans, wheat flour, semolina, paushtik atta (enriched flour) and several dried fruits, have been treated with EDB + MB combinations with cent per cent success. The residues obtained in these commodities did not exceed the permissible limits prescribed by different countries of the world for the fumigants.⁷⁻⁸ In terms of total tonnage, it is estimated that about 2 million tons of the food commodities have already been treated by these fumigants in India since 1957. The level of residues of the fumigant obtained on different commodities and the effect of this on quality, are given in Table B.

IV. Operational hazards (hazards to Operators during fumigation)

A highly poisonous chemical does not give rise to operational hazard, if handled with proper understanding and with due regard to its properties. Most often, a less toxic chemical can give rise to more number of accidents than the more toxic substance as it is often handled with proper care, while the less toxic chemical is used without proper regard to its toxicological properties. This fact has been borne out by several accident surveys carried out in some countries. Comparative properties with special reference to the practical applications of the commonly-used fumigants are presented in Tables D, E and F.

TABLE B

Grain	Fumi- gant	Residue ppm (as inorganic Er.)	Effect on germina- tion	Organo- leptic quality	Baking or cooking quality	Eff- ection vit- mins	Safe/storage single fumigation
Wheat	EDB	7-12	No effect	Good	Not affec- ted	Nil	3 months
	EDB+MB	5-8	"	"	"	"	10-12 "
Paddy	EDB	4-9	"	"	"	"	8 "
	EDB+MB	5-6	"	"	"	"	12-24 "
Rice	EDB	6-9	"	"	"	"	3 "
	EDB+MB	4-6	"	"	"	"	10-12 "
Jowar	EDB	8-11	"	"	"	"	2 "
	EDB+MB	4-6	"	"	"	"	10-12 "
Turmeric	EDB	9-14	-	"	"	"	4-5 "
	EDB+MB	8-1	-	"	"	-	12-16 "
Coffee	EDB+MB	9-3	-	"	-	-	9-12 "

Comprative properties of ethylene dibromide
and ther commonly used fumigants.

TABLE D

Compantive properties and toxicities to *S.oryzae*.

Fumigant	<i>Sitophilus</i> <i>oryzae</i> LD 95 Expo. 6 hrs mg/lit	Permissible limit in atmosphere mg/cu.m.	Fire hazard fl.pt°C	Penetration through bulk V.P.@ 20-25°C	90 B.P.
Carbon disulphide	50	62.4	-25	380	46.3
Ethylene dichloride	123	400	15	79	83.7
Carbon tetrachloride	370	160	nil	140	76.8
Ethylene Oxide	10.4	90	Highly infla- mmble	1100	10.7
Methyl bromide	6.1	80	65	1820	3.6
Ethylene dibromide	10	190	nil	11	131.6

TABLE E

Commercial dosage of fumigant mixture and their operational safety.

Fumigant	Commercial dosage	Exposure period (days)	Minimum No. of fumigations required in 12 months	Operational safety for operators	Cost per 20 tons of grain 'Rs.*
per 1000 c.ft					
EDCT (Ethylene Dichloride+Carbon tetra-chloride)	25-35 lbs.	2-6	4	safe	100
Chlorofume (EDB.CS ₂ -chloroform)	18-20 "	2-4	3	not safe	-
EDB(Ethylene dibromide	3.5-4.5 "	6-7	3	safe	30
MB(Methyl bromide)	2 "	1-2	1	not safe	12
DUROFUME(EDB+MB) (Ethylene dibromide -Methylbromide)	1.5-2 "	1.5-2	1	safe	7

* Indian Rupee.

TABLE F.

Lethal concentration in atmosphere for rats and rabbits.

Fumigant	Lethal concentration mg/lit. (C)	Exposure minutes (T)	Time concentration product (CXT) for lethality mgX min/ lit	Permissible concentration (ppm)
Carbon disulphide	16	375	6,000	20
Carbon tetrachloride	90	70	6,300	25
Chloroform	42.9	20	860	100
Ethylene dichloride	40	25	1,000	50
Methyl bromide	20	84	1,680	20
Ethylene dibromide	30.7	60	1,800	25
*Hydrogen cyanide	0.2	5	1.0	10
Ethylene oxide	90	90	8,100	50
*Hydrogen sulphide	1.5	2	3.0	20
O-Xylene	30	60	1,800	200
*Sulphur dioxide	2	20	40	5

* In spite of the high toxicities these were most extensively used in previous years.

A perusal of the Tables D, E and F will indicate that a less toxic substance required more quantities to be handled while an efficient fumigant required less dosage. The factors governing the potential hazards to operators are (i) Concentration and exposure periods, (ii) Boiling point, (iii) rate of volatilisation, (iv) period required for handling and administration, (v) technique applied for administration and (vi) metabolism, detoxification and nature of biochemical reaction in vivo in mammals.

Extensively-used fumigants, such as sulphur dioxide, hydrocyanic acid and carbon disulphide, are much more toxic than the fumigants, such as methyl bromide, ethylene dibromide and ethylene oxide. These are also many times more volatile than ethylene dibromide. It is also interesting to note that even Xylene is having the same Lethal concentration to mammals with 60 minutes as the exposure period. In a chemical laboratory, H_2S (Hydrogen sulphide) is extensively used which is extremely toxic and being 600 times more toxic than ethylene dibromide. The permissible concentration in atmosphere is although the lowest for sulphur dioxide, it is the oldest and extensively used fumigant in India and other tropical countries.

At present, a mixture of ethylene dichloride and carbon tetrachloride (EDCT) is being used in India. The potential hazard of this mixture is much more than that of ethylene dibromide under the existing conditions of use.

The concentrations of EDCT mixture and EDB mixture in the atmosphere to which the operators are exposed during the administration on grain bag stacks in warehouses by the usual procedure (CWC, 1959)²¹ of application of EDCT and EDB-MB applied by the tubing system, have been estimated, which are given in the Table C. It is evident that the operator is exposed to higher concentration than the safe and permissible concentrations during fumigation with EDCT under existing practice of its use in warehouse. Operational safety is not achieved with EDCT fumigant mixture under the conditions of its use. Use of gas mask canisters and other protective kits are absolutely necessary for fumigation with EDCT-mixture. Service time for canister being less for EDCT, it entails considerable expenditure under the usual technique for EDCT application.

Munro²² has critically assessed the fumigants and stated that carbon tetrachloride is not very toxic to insects, but is very toxic to humans. He emphasized the need for great care needed to avoid breathing of its vapours even in low concentrations. Reviewing the behaviour of the mixture of EDCT, he states that it does not penetrate the commodities very well and long exposures are needed to bring about good results.

It has been observed that the large quantities of the EDCT mixtures soak the grain treated and often persists in absorbed conditions for several weeks. The fumigant retained on grain needs critical studies from nutritional and toxicological angles under the conditions of the application.

TABLE G

Fumigant	Probable safe ¹ concentration for exposure for operators (ppm).	During administra- tion concentration reached in the immediate vicinity one of operators.	Leak detec- tion by Halide Detectors
EDCT	100	500-1200	cannot be used
CS ₂	3.2	-	-do-
MB + EDB	100	0.2 ppm*	can be used

1: Maraden, C., Solvents Manual, Elsevier Press (1954):
Batty, P.A., (1959).

*: Applied by technique of Durofume Process¹⁷.

Methyl bromide, as a pure chemical, has an insidious effect, if handled without precautionary measures due to the absence of perceptible odour at ordinary concentrations. In spite of its insidious nature, it has been safely used in large quantities in all parts of the world for over 25 years. The few accidents that have occurred in early stages of its application may be attributed to gross carelessness²². The disadvantage of methyl bromide for having no discernible odour is overcome by adding small amount of chloropicrin as a warning agent. At temperatures below 15°C, the action of chloropicrin, used at 2% concentration in methyl bromide, as a practical lachrymatory agent during fumigations, is satisfactory. When applied at 24°C and above, separation of chloropicrin from methyl bromide near the nozzle of the cylinder takes place due to the cooling and most of it is retained in the tubing. Under the conditions of temperature, chloropicrin at 2% level in methyl bromide does not give the desired warning. Ethylene dibromide, when added to methyl bromide containing chloropicrin increased the safety factor due to its characteristic odour and carrying chloropicrin with the fumigant mixture without the separation at the nozzle of the cylinder. The usual halide detector are highly sensitive to very low concentrations (below 17 ppm) of the fumigant mixture.

V. Significance of residues of ethylene dibromide and methyl bromide in foodstuffs.

Ethylene dibromide in presence of moisture gives very low quantities of glycol and hydrogen bromide ($\text{CH}_2\text{Br} + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{OH} + \text{HBr}$)²³⁻²⁶. During fumigation, the quantity of the fumigants which undergo this type of hydrolysis, is a very small fraction of the dosage applied.

Most of the bromide present in ethylene dibromide fumigated

foodstuffs were shown to be in the form of inorganic residue. This residual bromide is resulted from the reaction of EDB with grain constituents. The nature of the residue of ethylene dibromide was found to be of similar nature as that of methyl bromide. The chemical reaction on the other hand, was more intensive and extensive with methyl bromide than that of ethylene dibromide. This is accountable as methyl bromide is chemically more reactive than EDB, the nature of the residual bromide is reported to be identical in both the cases. The solubility of the residue in water, denotes its inorganic nature²⁴.

Bendi, Olomucki and Calderon²⁷ studied the effect of high amounts of absorbed ethylene dibromide in feed on the production of eggs in experimental hens. It was concluded that grains fumigated with EDB can be used for poultry feeding, provided that, it contained no free EDB. They considered that an amount of 10 ppm as EDB was permissible upper limit. Under the conditions of use, EDB is described and escapes to the atmosphere within a period of 2 weeks in the post-exposure period. The feeding of poultry even during this period with grain containing¹⁰ to 15 ppm of EDB has been found to be safe. The conditions of these experiments can never be achieved in normal fumigation as a dosage of 1000 mg EDB/litre has been used, while saturation concentration of EDB as gas is only 112 mg/litre at 25°C.

More detailed study of the residual aspects of ethylene dibromide on foodgrains with special reference to its toxicological and nutritional aspects have been carried out by Bridges²⁴ and others^{27,429}. Such a critical study with toxicological and nutritional approach with EDCT mixtures. In foodstuff is fumigated with ethylene dibromide several types of residual contamination depending on the subsequent treatment of the grain must be considered²⁴. Those are enumerated below:

(i) Contamination of ethylene dibromide due to inadequate airing:

Compared with methyl bromide, the rate of airing is considerably small and ethylene dibromide can be retained unchanged for a considerable period. Wheat contained in appreciable amount of residual bromide after 12 days. But, on milling, the residual bromide concentration fell to zero even under the condition in U.K.²⁴. Under Indian conditions, the temperature of the atmosphere is fairly high and the rate of volatilization of ethylene dibromide is rapid. Under the conditions of use, ethylene dibromide will be retained in the grains fumigated at much lower concentration than that obtained under the conditions in temperate countries.

(ii) Contamination by the product of reaction between ethylene dibromide and of wheat.

A possible site of such reaction is with SCH_3 group of the methionine constituent of the protein¹⁹. Under the conditions of usage, the ethylene dibromide vapour which is retained in the original form (i.e. as ethylene dibromide) in the grain as a result of its sorptive properties, will aerate on being milled and also during heating and cooking, the organic vapours will escape. Although, during heating

a portion of ethylene dibromide get converted into ethylene glycol and hydrogen bromide, with normal dosages, the formation of glycol has not been in detectable amounts. Ethylene dibromide concentration fell to zero in rice, wheat and pulses in the post-exposure storage period in all the experimental stocks under commercial conditions in India.

Considering the nutritional significance of residues resulting from ethylene dibromide fumigation, Bridges²⁴ stated "any reduction of the ~~of-the~~ content of essential amino acids due to reaction between the ethylene dibromide and the wheat protein during fumigation and airing would be extremely small. The largest water-soluble bromide residue of ethylene dibromide recorded in the case of fumigated milled wheat was 9 ppm. Assuming that, a simple bimolecular reaction occurs with the methionine only, then such a residue would represent a reduction of less than 0.4% of the total methionine content as given for a typical wheat flour. As the glycol determinations were made in this case on milled wheat exposed to ethylene dibromide under extreme conditions, such a reduction is most unlikely to occur in practice. In whole grain, this residue is extremely low".

Heuser²⁹, in a recent study on ethylene dibromide residues in wheat and wheat products, stated that "the significance of EDB residues may be lessened by these considerations".

1. They would appear only in the upper part of a treated bulk of grain, unless forced circulation were used;
2. At the time of milling, the fumigated grain would normally be diluted with grain from other sources;
3. Unchanged EDB is broken down to relatively harmless components or vapourised in the baking process.

These above considerations are even applicable to the conditions in U.K., where atmospheric temperatures are significantly lower than that of India. However, he further stated that "it is advantageous to fumigate grain with EDB when warm, since far less fumigant is sorbed and the rate of airing is greater.

In U.K., U.S.A., and Canada, EDB singly or in combination with Carbon tetrachloride is used for fumigating bulk in silos. In silo storage, the residue in grain is likely to be more than the bag storage. Under flat or bag storage conditions, the residues of EDB will be far less in magnitude under Indian and tropical conditions.

Methyl bromide

The chemical fate of methyl bromide absorbed by wheat under the conditions of fumigations have also been recorded and the major proportion of the fumigant residues could be accounted in the protein fraction. This has been used for many years for fumigating the infested wheat and other cereals in the U.K., Canada, U.S.A., Germany, Japan, Australia, Israel, India and many other countries of the world. It has been known for some time that the residual fumigant retained

by the fumigated and aired cereals was almost entirely decomposed with the formation of inorganic bromide. Winteringham and Harrison²⁵ studied the rates of sorption of methyl bromide by whole and milled wheat. The gluten although present in smaller proportion than the starch, was largely responsible for the physical absorption and apparently for the chemical decomposition of the absorbed methyl bromide.

It is interesting to note that despite the high glutamic acid content of wheat protein (about 30% by weight), the proportion of O-methylation found was relatively small. Winteringham *et al*²⁶, remarked that methyl bromide absorbed by wheat under conditions of fumigation undergo chemical decomposition with the formation of inorganic bromide and a series of methylated derivatives. At the concentration in fumigated cereals (less than 500 ppm), this bromide was unlikely to be toxic. The production of free methanol as a result of hydrolysis was about 10% or less. Bridges²⁷ in a later study, found that the reaction between methyl bromide and nitrogen containing groups of wheat protein was highly specific being mainly of methylation of the imidazole rings of the histidine residues. They also observed that there was no appreciable loss of any of the amino acids in wheat protein by N-methylation when wheat flour was fumigated with methyl bromide under normal conditions.

Winteringham²⁸ studied the possible toxicological and nutritional significance of fumigating wheat with methyl bromide. By a systematic study of the nature of methyl bromide residue in fumigated wheat, an attempt was made to provide the information on the nature of fumigant residue and also to make an assessment of any health risk that may be involved. It is concluded on the basis of the data at present available on various aspects of the problem that there is no evidence of risk to consumer health as a result of using methyl bromide as a fumigant for cereals and other food-grains.

It may be pointed out that it is the most extensively used fumigant which has received universal acceptance for treatment of foodstuffs. Comparative data have been obtained at this Institute on the residue levels of ethylene dibromide on some foodgrains and other commodities, are presented in Table H.

Detailed studies on fumigation of oil-bearing materials have been carried out by Srinivasan *et al*³¹. The results obtained with different components of oil seeds such as oils, proteins and carbohydrates and whole seeds have shown that MB in general, yield more residues in permanent form than EDB. Protein fractions in seed, account for the maximum residue of MB, fat on the other hand, sorb largely EDB and depending on the structure of the seed the amounts retained as residues vary. A compact seed like groundnut does not give rise to high retention of EDB as such. Dry fatty fruits, such as cashewnut and walnut retain EDB in significant amounts. Copra, on the other hand, does not retain the fumigant in high amounts after the aeration periods. Further, it has been observed that presence of low quantities of EDB in MB lowers the dosage requirement considerably and it lowers the rate of reaction of MB with protein and keeps the residues very low and within safe limits. Residue data are presented in Table I.

TABLE H

Commodity	Bromide residues (ppm)				Permissible limit (ppm) under*		
	EDB	MB	EDB 1:1	MB 1:3	USFDA	Canada	India
Rice	7	9	6	-	50	50	50
Wheat	8	12	7	-	50	50	50
Jowar	11	3	5	-	50	50	50
Bengal gram	7	22	4	-	-	-	-
Groundnut kernel	21	26	15	20	200	200	-
Groundnut cake	16	53	25	-	-	-	-
Coffee beans	9	16	11	-	-	-	-
Copra (Split)	32	22	19	15	100	200	-
Cocoanut cake	10	60	26	-	-	-	-

TABLE I.

Commodity	Bromide residues in ppm (100 mg/litre for 100 hrs)		
	EDB	MB	EDB-MB (1:3)
<u>Ground nut</u>			
Decuticled kernel	19.5	62.4	29
Oil	62.4	32.5	-
Defatted flour	15.5	154.7	-
<u>Cashewnuts</u>			
Kernel	71.5	96.2	65
Oil	76.7	42.8	-
Defatted flour	15.6	168	-
<u>Copra</u>			
Copra cup	20.0	35.1	22
Oil	39.0	10.4	-
Defatted flour	14.3	170	-

VII. Conclusions.

Considering the facts, that (a) the nature of residue of methyl bromide and ethylene dibromide as similar; (b) the reaction with the composition of food is more extensive and intensive with methyl bromide than ethylene dibromide and the permanent residus in fumigated foodgrains is much more in the case of methyl bromide; (c) both ethylene dibromide and methyl bromide are in use in U.S.A., Canada, U.K., and many other countries of the world, as grain fumigants for infestation control; (d) permissible limits in fruits, vegetables, foodgrains, spices, pulses, have been prescribed by USA, UK, Canada, and some continental countries at 50-200 ppm levels; (e) organic residue of ethylene dibromide is exempted under US food laws, as the fumigant is not retained permanantly by grains; (f) during the post-exposure periods, all the organic vapours of the fumigant escape to the atmosphere; (g) cooking, milling and washing reduce the level of the fumigants to insignificant levels which are innocuous even if the un-aerated grains are taken and processed for human consumption; (h) long-term feeding trails on rats with high amounts of residues, than what is normally obtained in food articles as a result of fumigation, have not indicated any toxicological hazards or nutritional disturbance; (i) ethylene dibromide is the cheapest brominated fumigant, and can be produced in mass scale in many countries; (j) it has been used on a very extensive scale under field conditions, without any report whatsoever, on the undesirable effect on human health under Indian conditions, over a period of 7 years; (k) comparatively more hazardous fumigants are in general use to-day; the application of ethylene dibromide, either singly or in combination with methyl bromide, may be recommended on foodgrains, pulses and spices, as a grain fumigant in India, and other tropical countries.

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BASIC STUDIES:

BEHAVIOR OF ETHYLENE DIBROMIDE, METHYL BROMIDE, AND THEIR MIXTURES

I. In columns of grains and milled materials.

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SUMMARY

The stratification of ethylene dibromide (EDB) and methyl bromide (MB) and their mixtures in 5-ft. columns of jowar and wheat semolina, was studied. Mixing MB with EDB even in as low quantities as 5-10% (w/w) improved the penetration of EDB. The 1:1 mixture was better than MB used alone, as evidenced by the intergranular gas concentration and insect mortality. In semolina columns out of the mixtures 1:1, 1:2, and 1:3, (w/w), 1:2 was the best, at both 68 and 100°F. Higher proportions of MB than 1:2 (EDB:MB) tended to reduce insect mortality at 100°F. The bromide residues were lower at 86 than at 100°F, and increased with the increased proportions of MB. The differential analysis of the gas samples with monoethanolamine and ethanolic potassium hydroxide reagents demonstrated the elution of EDB to the bottom of the columns along with MB. Progressive enrichment of EDB at the top and MB at the bottom portions of the grain and semolina columns was observed during the exposure.

INTRODUCTION

The toxicity of the two fumigants ethylene dibromide (EDB) and methyl bromide (MB) to grain pests is well established (Lindgren et al., 1954; Brown, 1959; Aman et al., 1946). A great drawback of ethylene dibromide as a stored-product fumigant is its low penetration of grain in bulk, because of its low vapor pressure and high sorption by the commodities and walls of fumatoria (Aman et al., 1946; Majumder and Muthu, 1960). As to its insecticidal effects, there is evidence that it is even more toxic than methyl bromide, especially to the immature stages of the insects (Krohne and Lindgren, 1958). Methyl bromide, in contrast, has, besides high toxicity to insect species, a very efficient penetration into grain in bulk and even into packaged goods, though sorption and reaction with protein-rich food is greater with methyl bromide than with ethylene dibromide. (Winteringham et al., 1955; Srinivasan et al., 1961). In some commercial trials with methyl bromide in stacks of cereals it was observed that the concentration at the top decreased rapidly and left the portion underdosed, especially on warm days. EDB, in contrast, did not sink to the bottom layers even in 96 hr of exposure. A combination of the two, however, maintained an integrated over-all concentration of the two components at all levels in a tall grainbag stack, even without forced circulation.

No report is available on the behaviour of a mixture of ethylene dibromide and methyl bromide in columns of grains and their milled

products under different temperatures. The present investigation was undertaken to study the behaviour of the mixture with special reference to stratification of the components at different temperature fumigation.

EXPERIMENTAL

Fumatoria. The fumigation trials were conducted in 50-L 5-ft-high cylindrical mild-steel fumatoria (Fig.1). The cylinder contained three

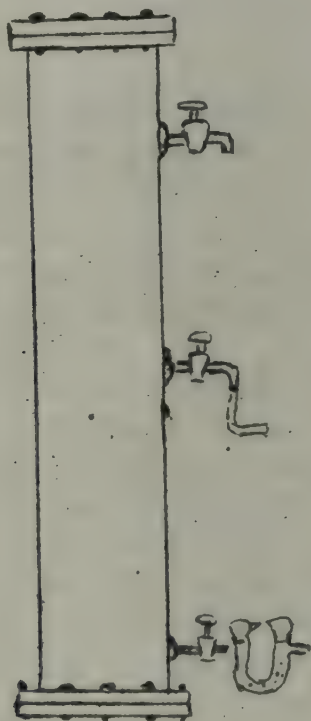


Fig.1. Showing mildsteel column with three insect exposure tubes at top, middle, and bottom. An airflow indicator is attached at the middle spout.

spouts: at top, middle, and bottom. Glass capillary stopcocks in coated rubber bungs were inserted tightly at the top and bottom spouts. The middle spout carried an insect-exposure tube provided with a capillary stopcock to act as an observation window (Fig.1).

Load. The loads, jowar (sorghum) and wheat semolina, occupied 4/5 of the space in the fumatorium. Jowar had a moisture content of 12%, and a dockage of 0.4%. Wheat semolina carried a moderate infestation of *Tribolium castaneum* and *Oryzaephilus surinamensis*, and jowar carried a heavy infestation of both *Calandra oryzae* and *T. castaneum*.

Test insects. Test insects consisted of 3-4 week-old *T. castaneum* adults in rimmed glass tubes 2 in. long and of $\frac{1}{2}$ in. internal diameter, with the ends closed by muslin cloth and secured by rubber bands. These were placed at the top, middle, and bottom positions while the cylinders were being loaded. A little wheat flour was kept inside the tubes to serve as food. In addition to the tubes inside, insect exposure tubes were also attached with the sampling points of the fumigation cylinders to provide a visual indication of insect mortality during exposure at these points. The materials, along with the test insects, were conditioned for 48 hr. at each experimental temperature before the fumigants were applied.

Application of fumigants: Ethylene dibromide (E. Merck) sp. gr. 2.172, 25°/25°, was used. A micropipette of 0.01-ml graduation fitted with a 5-ml glass syringe was used to suck the desired quantity of EDB. The pipette tip was connected to the top stopcock by a short piece of rubber tubing forming a butt joint, and the stopcock of the evacuated cylinder was opened. The traces of the fumigant in the syringe were scrubbed by allowing the air to flow through the syringe by removing the plunger, and brought to atmospheric pressure before the stopcock was closed.

∠ the stopcocks of top, middle & bottom

Ethyl bromide (A.R. grade) was used for fumigation in fumatoria

Methyl bromide (May & Baker) was applied to experimental fumatoria by the following technique. The required amount of methyl bromide was calculated and converted to the volume it occupies at the prevailing temperature and barometric pressure. The glass flask chosen closely approximated the required volume and was fitted with a ground-glass standard male joint having 2 capillary tubes, one placed laterally and another in the center. The central stopcock had a long capillary tube reaching to the bottom, and the laterally placed stopcock opened at the top, resembling a "Strand flask" (Fig. 2). This flask was evacuated to 0.1 mm absolute

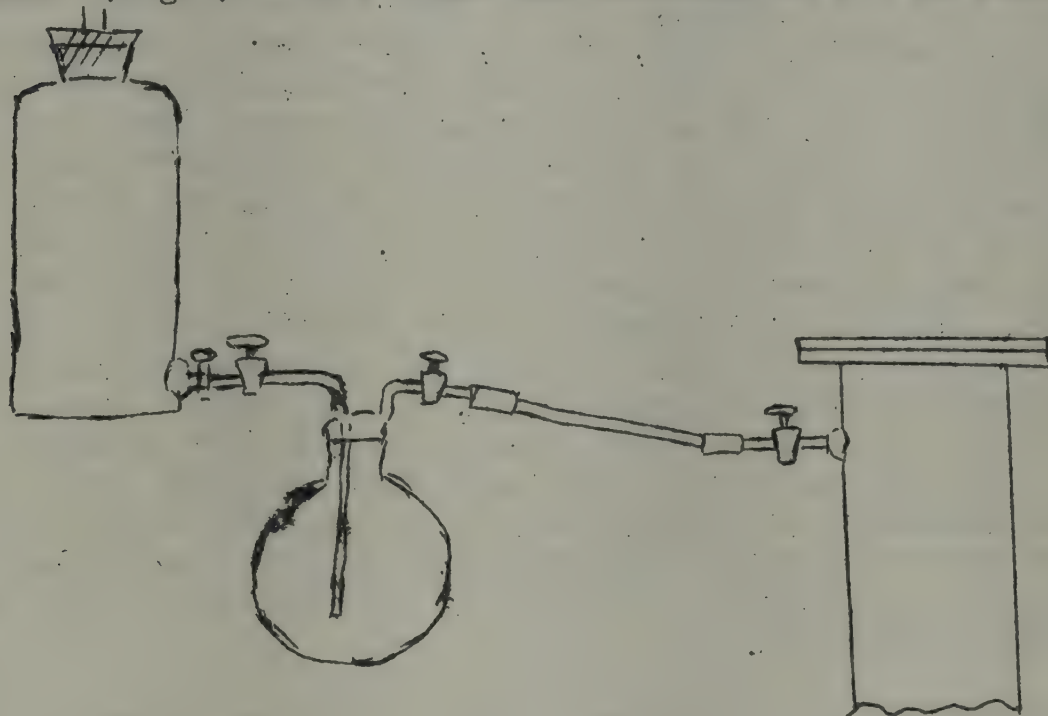


Fig. 2. Methyl bromide dosing apparatus.

pressure with a rotary vacuum pump. After the evacuation, the stopcock on the flask connecting the vacuum pump was closed and connected to the methyl-bromide-holding chamber, which is essentially a methyl bromide cylinder without a dip tube. The valve of the methyl bromide cylinder was manipulated to satisfy the vacuum with methyl bromide, and the pressure inside the flask was brought to atmospheric pressure. The flask was also weighed after evacuation and after being filled with methyl bromide. The difference in weights gave the quantity of methyl bromide taken into the flask. A vacuum of 5 in. was established in the fumatoria before the fumigants were administered. MB was administered to the evacuated fumigation column, from the top spout, replacing the gas from the flask by running CaCl_2 -saturated water from an aspirator. When EDB and MB were applied to the same fumatorium, There was a drop in the vacuum of the fumatorium. The pressure inside the fumatorium was restored by allowing air from outside, and the end point of suction was noted with the help of a sensitive air-flow indicator (Muthu, 1961).

Doses. Ethylene dibromide and methyl bromide, as single fumigants and also in mixtures, were administered at doses of 32 and 48 mg. per liter for jowar and wheat semolina, respectively.

Gas mixtures and temperatures. In jowar, the mixture was 5, 10, 25, and 50% MB in EDB at room temperature ($77 \pm 2^\circ\text{F}$). In wheat semolina, the mixture was 50, 66, and 75% MB in EDB at 68 and 100°F .

Gas sampling and analysis. Gas concentrations were estimated at 5, 24, 48, 72, 96, and 120 hr. in jowar, and at 4, 8, 24, 48, 72, 96, and 120 hr in wheat semolina.

Ethylene dibromide was estimated by the method of Muthu and Majumder (1960), and methyl bromide by the method of Stenger et al. (1939). For the estimation of methyl bromide and ethylene dibromide fractions from the mixtures, low and high-temperature hydrolysis with monoethanolamine (Berck, 1961a), a freeze-separation technique for fractionation of the two components (Muthu, 1960), and differential hydrolysis with KOH and monoethanolamine were investigated. Berck (1961a) reported that the reaction of ethylene dibromide with monoethanolamine is completely suppressed at 3°C , and at this temperature methyl bromide reacts quantitatively, making it possible to estimate methyl bromide selectively from a mixture of these two fumigants. Differential hydrolysis with monoethanolamine of methyl bromide and ethylene dibromide at low and high temperature did not give true estimates of the components, because both fumigants hydrolyzed at all temperatures with monoethanolamine (Muthu and Majumder, 1960). A freeze separation method was also tried for fractionating ethylene dibromide and methyl bromide, but the high solubility of methyl bromide in ethylene dibromide and the reaction of both the fumigants at even $3-5^\circ\text{C}$ made it difficult to estimate either of the components selectively.

A method suggested by Heuser (1961) was found to be more reliable for differential analysis of MB and EDB than the methods described above. The procedure consists of drawing duplicate samples and subjecting one sample to dehydro-halogenation with 2% alcoholic potassium hydroxide (Kolthoff and Yutzy, 1937) and the other sample to monoethanolamine hydrolysis (Stenger et al., 1939; Sinclair and Crandall, 1952). Monoethanolamine hydrolyzed both EDB and MB completely, whereas ethanolic KOH gave 50% recovery of EDB and 100% recovery of MB. The individual components were calculated after first getting the bromide values by both methods. The concentration-time (CT) curves were drawn, from which the CT products were calculated by measuring the area under the curves.

Insect mortality counts. The death time of the insects in the observation windows was noted in each trial. After exposure, the tubes from inside as well as outside ('windows') the columns were examined for insect mortality, and were kept for 15 days on food before final mortality counts were taken.

Bromide residues: Bromide residues were determined on samples drawn from the top and bottom portions of the fumigation cylinder after aeration by the method described by Young et al. (1943).

RESULTS AND DISCUSSION: Stratification of ethylene dibromide, methyl bromide, and their mixtures in jowar columns. In jowar columns the concentration of ethylene dibromide at the bottom was extremely low and the CT product was even below 10 mg/hr/L in 24 hr of exposure to 32 mg/L. *T. castaneum* adults were not killed at the bottom and middle sampling points (Table 1). Increasing the concentration of

Table 1. Effect of the stratification of ethylene dibromide, methyl bromide and their mixtures in jowar columns on concentration-time products and mortality of *Tribolium castaneum*. (Dose: 32 mg/L at 77+ 2°F).

Fumigant %			Mortality in 48 hr (%)			Integrated CT products (Mg hr/L) ^a	
EDB	MB	Top	Middle	Bottom		24 hr	48 hr
100	0	100	0	0		202/0	372/38
95	5	100	47 ^b	0		136/0	214/43
90	10	100	100	13		213/7	362/55
75	25	100	100	34		274/29	422/96
50	50	100	100	100		272/72	656/298
0	100	100	100	100		630/88	759/169

a. Figure pairs are for top/bottom. b.*

MB in the mixture to the 25% level enhanced the CT products at the bottom to 29 and 96 mg hr/L at the end of 24 and 48 hr, respectively. Mortality of the test insects was 100% at all sampling points in a jowar column fumigated with 1:1 EDB-MB and 48 hr of exposure. Exposure for 72 hr also gave 100% mortality with 5 and 10% MB in EDB, although EDB alone was not adequate to give 100% mortality at the bottom of the jowar column at the end of 72 hr. The results strongly indicated the beneficial effect of adding MB to EDB even at 5-10% (w/w). On comparing the CT products and insect mortality results it was observed that 50% EDB with MB was significantly superior to MB alone under experimental conditions (Table 1). It was evident with a dose of 32 mg/L that 1:1 EDB-MB gave more uniform concentrations in the intergranular spaces of top and bottom of the grain column than did MB alone (Table 2). Although it is generally expected that a low free-space concentration of MB will be obtained with the 1:1 mixture at 32 mg/L and that the EDB fraction would be largely sorbed in the top portions of the grain column, higher CT products and a more uniform fumigant distribution were obtained with the mixture than with MB alone at the same dose. These indicated for jowar a comparatively lower rate of sorption and reaction with the mixture than with MB alone. Detailed studies are in progress on these aspects.

Data obtained on differential composition of the gas samples drawn from the top and bottom of the grain column show that EDB is sorbed at the top portion of the column whereas MB stratifies

*b. Mortality was 100% after post exposure incubation in wheat flour for 48 hrs.

TABLE -2

Effect of different proportions of methyl bromide in ethylene dibromide on the penetration to the bottom of jowar column at 77+ 20F (initial dose 32 mg/L.).

Exposure (hr)	MB:EDB					
	0:100	5:95	10:90	25:75	75:25	100:0
	(Mg/L, top/bottom)					
5	41.2/0.0	34.6/0.0	24.0/0.0	28.0/0.0	36.9/0.0	58.2/4.6
24	18.1/0.9	13.8/0.9	8.5/2.1	9.3/2.1	9.3/7.1	11.0/4.6
	6.2/1.7	6.0/2.8	5.5/4.1	7.5/6.3	11.3/8.2	0.0/2.5
Bromide residue ppm	11.0/1.0	9.5/4.0	8.5/6.5	5.7/6.5	5.8/7.9	8.0/12.5

to the bottom comparatively quickly, with the proportion of the mixture changing considerably from the original ratio of the components (Table 3). There was enrichment of MB in the bottom portion.

TABLE -3

Elution of ethylene dibromide in jowar columns when used in 1: 1 mixture with methyl bromide (32 mg/L dose 77+20F.)

Exp(hr)	EDB+MB (1:1)			MB alone	EDB alone
	(Mg/L)	(%EDB)	(%MB)	(Mg/L)	(Mg/L)
Top					
5	36.9	46	54	58.2	41.2
24	13.9	71	29	11.0	18.1
48	11.3	66	34	0.0	6.2
Bottom					
5	0.0	0	0	4.6	0.0
24	7.1	29	71	4.6	0.9
48	8.2	42	58	2.5	1.7

Under the experimental conditions, however, separation of the components was not complete in jowar columns. The differential gas analysis for MB and EDB showed that low concentrations of MB in EDB were also eluted to the bottom. The action of MB as a carrier gas for EDB in the grain column could be noted and explained on chromatographic principles. Significant amounts of EDB were obtained along with MB in gas samples from the bottom, as indicated by KOH and monoethanolamine hydrolysis methods of analysis, unless EDB was used alone, when it did not descend to the bottom within the exposure period.

Incubation tests revealed that EDB used alone showed low CT products at the lower strata of the jowar columns and also exhibited a delayed action on the surviving T. castaneum adults (Table 1).

Residues on grain samples from different location were greater with MB alone than with mixtures of EDB and MB.

Stratification of EDB, MB, and EDB-MB in semolina. In semolina columns, an attempt was made to study the behaviour of mixtures of EDB in MB in proportions (0, 25, 33, and 50% EDB in MB) and temperatures (67+1 and 100+1°F) different from those used with jowar.

The CT of 1:1, 1:2 and 1:3 mixtures ranged between 151 and 230 at the bottom in 48 hr at both temperatures (Table 4). The differences between the CT products of 1:1, 1:2, and 1:3 mixtures at 68°F were

TABLE-4

Effect of different proportions of ethylene dibromide in methyl bromide on the concentration-time-product and mortality of Tribolium castaneum and semolina columns at different temperatures (48 mg/L dose).

EDB:MB	Temp (°F)	Fumigant concentration (Mg/L) ^b		Concentration - time product ^c mg hr/L (Bottom)	% Mortality ^a at	
		48 hr	48 hr		48 hr	15 days ^b
1:1	68	41.6/3.1	8.6/6.2	223	100/25	.../100
	100	42.9/2.8	5.2/5.5	168	100/47	.../100
1:2	68	47.3/2.9	8.9/5.6	230	100/100	...
	100	64.5/2.9	7.4/5.9	195	100/87	/100
1:3	68	47.7/6.0	4.5/7.5	218	100/100	...
	100	37.3/6.4	5.7/3.7	151	100/38	/ 72
0:1	68	40.9/7.2	17.2/6.2	220	100/100	...
	100	35.8/2.1	5.4/2.6	93	100/10	/23

^a Figure pairs are for top/bottom.

^b Post-exposure incubation for 15 days.

small, and recorded within 210 and 230 mg hr/L. In semolina columns the CT products were highest with the 1:2 mixture. Insect mortality showed significant differences at different temperatures. In contrast to the general concept, mortalities were lower at 100 than 68°F. At all temperatures, 1:2 mixture showed significantly higher toxicity than the other mixtures. Considering both mortality and CT products data, it became evident that, with the load of semolina, although the CT products did not show wide differences at temperatures 68 and 100°F, mortality values varied significantly between exposure

temperatures. Changing the proportions from 1:2 to 1:3 tended to reduce mortality (Table 4). Under the experimental conditions, 1:2 was best for disinfestation of semolina as indicated by CT products and insect mortality.

Differential analysis of EDB and MB showed remarkable differences in the gas composition with changes in proportions (Table 5). In all combinations (1:1), 1:2, and 1:3) the elution of EDB with MB to bottom could be evidenced by the hydrolysis of duplicate gas samples by alcoholic KOH and monoethanolamine reagents. There was no doubt that the components separated during passage from top to bottom, though not completely. At the top, a gradual enrichment of EDB was noted, whereas MB was enriched at the bottom at all temperatures tried (Table 5). More EDB was eluted to the bottom at 100 than at 68°C.

TABLE 5.

Stratification^a of ethylene dibromide and methyl bromide in wheat semolina columns at 68 and 100°F.

Fumigant mixture (%)			Exposure (hr)						Bronide ^b residue (ppm)
			4		48				
EDB	MB	Temp (°F)	EDB (Mg/L)	MB (Mg/L)	EDB (%)	EDB (Mg/L)	MB (Mg/L)	EDB (%)	
50	50	68	21.8/0.0	19.8/3.1	52/0	5.9/0.3	2.7/5.9	68/5	26
		100	20.7/0.0	22.2/2.8	48/0	4.0/0.5	1.2/5.0	71/10	35
33	67	68	14.3/0.0	33.0/2.9	30/0	4.2/0.4	4.7/5.2	47/7	29
		100	20.7/0.4	43.8/2.5	45/13	5.4/0.9	2.4/5.0	69/16	42
25	75	68	23.6/...	24.1/6.0	42/...	4.5/0.5	0.9/7.0	83/7	29
		100	18.8/0.3	18.5/6.1	50/5	5.1/0.7	0.6/3.0	88/18	56
0	100	68	.../...	40.9/7.2	.../...	.../...	17.2/6.2	.../...	55
		100	.../...	35.8/2.1	.../...	.../...	0.4/2.6	.../...	69

^a Figure pairs are for top/bottom

^b Composite sample drawn after 120 hr exposure and aerated for 48 hr.

The average bromide residue increased with the proportion of MB and with temperature. Detailed studies are in progress to examine the rates of separation of 1:2 mixtures of different temperatures, and their effect on the residues at different points in tall columns of wheat semolina.

It is interesting to note that at high temperatures the insect mortality was lowered with the increase in the proportion of methyl bromide. The lowering of the toxicity of methyl bromide to the test insect at 100°F was indicated by the results reported above. Evidence

was also obtained on the comparatively greater reaction of methyl bromide in the absence of ethylene dibromide with jowar or wheat semolina. Further, the reaction was also higher at 100°F than at 68°F. These pointed to the possibility of a higher rate of reaction as a factor for bringing down the integranular concentration and consequent lowered CT product, especially when methyl bromide was used as a single fumigant. These results pointed to the need of a critical study on the toxicity and mode of action of methyl bromide on stored grain pests at different temperatures in the presence and absence of load in the fumatoria.

Berck (1961b) recently reported the results of a study on some mixtures of fumigants in grain columns at 48°F. At this low temperature a fumigant like ethylene dibromide should normally reach the freezing point and change to the solid state, whereas the behaviour of this fumigant in combination with methyl bromide at higher temperatures—68, 77, and 100°F, as tried in the present investigation—will be quite different and will exert a much more beneficial effect than at 48°F. Differential analysis of ethylene dibromide and methyl bromide from their mixtures would need a specific method for the separation and estimation. The present investigation, utilizing, the total hydrolysis of ethylene dibromide and methyl bromide by monoethanolamine and partial hydrolysis of ethylene dibromide with alcoholic KOH, seems to have given more reliable results regarding the behaviour of ethylene dibromide and methyl bromide in grain columns, with special reference to their stratification at different temperatures, than the results obtained by low- and high-temperatures hydrolysis with monoethanolamine.

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Controlled Large-scale Trials.

STUDIES ON AN IMPROVED PROPHYLACTIC PROCESS FOR PEST CONTROL IN STORED FOODS*

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A B S T R A C T

Cereals, pulses, spices, oilseeds, their processed products and dehydrated fruits and vegetables are attacked by the storage insect pests. The spoilage caused by insects in the tropics in stored foodstuffs, having moisture content less than 15%, is quite rapid due to the short life cycle of the insect species. Fumigant combinations have been screened for their suitability for disinfestation of stored, raw and processed foodgrains in columns, silos and gas-proof sheets. The physico-chemical behaviour and insecticidal toxicities of the fumigant components have been studied with special reference to the behaviour of ethylene dibromide in combination with other fumigants under different temperature conditions. Data on the distribution of fumigants, their residues and toxicity to the life stages of the tropical stored grain pests are reported.

Studies carried out on the development of pesticidal compositions for treatment of the bag stacks and individual packages of stored foodstuffs for preventing cross-infestation are described. Data have been collected on the relative persistence and biological efficacies of DDT, BHC, malathion, pyrethrin, lindane and dieldrin carried in oil and oil-in-water type emulsions. The relationship between the drop size and contact angle of the formulations, weave clearance of fabrics, infiltration time of pests and the persistence and biological efficacies of the pesticidal impregnation on the treated surfaces has been studied.

The techniques of application for the disinfestation process with ethylene dibromide and methylbromide combination and the prophylactic insecticidal treatment as can be applied in the tropical warehouses on bagged grains and other commodities have been outlined.

Cereals, pulses, spices, oilseeds, their processed products and dehydrated fruits and vegetables are attacked by insect pests during storage. Although, low moisture in dried products prevents fungal spoilage, all dehydrated animal and vegetable products are susceptible to insect-infestation.

Cereal grains and their processed products having grain like shape are first attacked by the rice weevil, Calandra oryzae and subsequently

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other pests such as the red flour beetle, Tribolium castaneum and the saw-toothed grain beetle, Oryzaephilus surinamensis, appear on them as secondary pests. The milled material with the mesh size below 18 is not normally attacked by C.oryzae. Processed foods containing spices are infested by the spice beetle Stegobium paniceum as the primary pest. C.oryzae & T.castaneum do not normally attack spices and seasoned (spiced) cereal products. Storage of these articles ~~in the articles~~ in the warehouses are carried out in different textile fabrics, laminated paper bags, and other flexible packaging films, which do not provide adequate barriers for the migratory stages of the pests.

The loss in storage due to insect infestation varies from 5 to 25 per cent in the cereals and their products during a storage period of 10 to 12 months in India. Large scale storage of bagged cereals, pulses, spices, oilseeds, milled cereals, macaroni products and coffee beans are carried out under warehouse conditions. The infestation control in stored foodstuffs requires a disinfestation process and also a technique for controlling cross-infestation from outside sources. The former is achieved by fumigation treatment of the stock and the latter by a prophylactic spray treatment with residual insecticides or by dusting on the peripheral aspect of the stack.

Curative treatment:

Large amount of data have been collected on methyl bromide as a fumigant of bagged commodities at the Pest Infestation Laboratory, U.K.¹, and other laboratories in U.S.A.², Canada³, France⁴, and Germany⁶. Detailed studies however, have not been carried out on the behaviour of methyl bromide under usual warehouse conditions with special reference to temperature effects. The common fumigants, singly and in combination were screened for their suitability for disinfestation of stored raw and processed foodgrains in columns (5' and 12' high) and under gas-proof sheets with bagged commodities^{6,7}.

Preliminary screening showed that out of the fumigants studied methyl bromide and ethylene dibromide combinations were the best for practical disinfestation in loaded mild steel columns and warehouses.

Studies were therefore, carried out with reference to the behaviour of ethylene dibromide and methyl bromide under different temperature conditions and data on the distribution of the fumigants in bagged commodities and their effect on the stored grain pests were collected. Detailed experimental procedure, differential composition of gas samples from different positions of grain and semolina columns and the distribution of fumigant residues are being reported elsewhere.

Data are presented on the following aspects:

- i) Doses required for 99% mortality of T.castaneum, C.oryzae, Araecerus fasciculatus, S.paniceum, Rhizopertha dominica and O.surinamensis, for EDB, MB and EDB & MB mixtures (Table -1)

ii) Stratification of EDB and MB in jowar (sorghum) columns and Semolina columns at 68° and 100°F. (Table-2)

iii) Fumigation of wheat flour under gas-proof sheets at different temperatures and (Table-3)

iv) Commercial trials with EDB-MB combinations, residues on commodities and the effect on insects. (Tables 4)

Prophylactic treatment:

Fumigation is a curative process. For insect free storage of foodstuffs under warehouse conditions the disinfection process should be accompanied by a prophylactic treatment to prevent reinfestation in the fumigated stack. To ensure permanent prophylaxis against insects the fumigation process also should be able to kill all the life stages (egg, larva, pupa and adult) present in all the layers of the bulk commodity in addition to the prevention of cross-infestation by an insect proof barrier.

Screening of the commonly available fabrics and films used for bagging of cereals and their processed foods have shown that either one or all of the pests such as C.oryzae, S.paniceum, A.fasciculatus, B.chinensis, Rhizopertha dominica, Periplaneta americana, Ephestia cautella and Corcyra cephalonica were able to penetrate through the packaging materials or lay eggs inside the bags by oviposition (Table-5)

Parkin⁹, Butterfield et al¹⁰ and Atkins and Greer¹¹ studied the effects of impregnating jute bags with DDT for storing grains. This was found unsuitable for storing flour because of the degree of pesticide contamination at the effective levels of insecticidal impregnation¹¹. Majumder and Pingale¹² observed that jute fabrics exhibited preferential absorption of lindane from o/w type emulsion which gave rise to the difficult problem of obtaining uniform insecticidal impregnation in large-scale insect proofing of jute bags. Further studies carried out by Majumder¹³ and Majumder et al¹⁴ showed that insect-proofed jute and other textile bags could be obtained by spraying with o/w type emulsion with a machine containing low volume spray nozzles and having regulated conveyor feeding arrangement for spraying empty bags. As compared to 1.8 kg., the usual water uptake of a standard B-twill bag from an emulsion bath, only 20 gms of water were taken up by 16-18 sq.ft. surface of bags in the latter process. Drying of the spray treated bags with the formulation described by Majumder et al¹⁴, was not difficult even in large-scale production.

Most often insecticidal treatment of bagged foodstuffs are required during storage in the warehouses of processed food factories. It is difficult to spray the interior of the loaded warehouse with water dispersible composition in view of moisture increase and fungal growth. Dusting with residual pesticidal formulations also cannot be carried out as it presents food contamination hazards. A study was therefore, taken up to develop a dry process for a prophylactic spray treatment

of the stacks of bagged commodities in situ, with a view to applying it in conjunction with the fumigation treatment.

Results of the comparative studies on the persistence and biological efficacies of low viscosity and high viscosity oil based BHC, DDT and malathion formulations are presented in Table-6. Studies were also carried out with reference to the weave clearance of different fabrics, spray deposits on the fabric surface, infiltration of insecticides through the weave clearance and exposure required for T. castaneum adults for their mortality (Table-7).

Warehouse trials:

Commercial scale trials were carried out with EDB and MB combinations and the methods of application were standardised. The usual metal cylinders were evacuated and the required volume of ethylene dibromide was sucked in and the residual vacuum was further utilized for filling methyl bromide. In cases of higher proportions of methyl bromide in combinations than 1:1 (EDB:MB. w/w), cooling of the evacuated cylinder while filling the gas was found advantageous. A typical assembly for the preparation of EDB-MB mixtures is shown in Fig. On small stacks of 200 to 400 bags, for applying ethylene dibromide and methyl bromide in different proportions, an applicator as shown in Fig. was used.

The application on bag stacks under gas-proof sheet was carried out by a system of tubings as practised for methyl bromide fumigation. Instead of spray nozzles at the exit points film vaporisers were used and in place of usual gas masks with canisters, air-hose of non-kinking and non-collapsible type was connected to the face piece. Remote control of the gas-proof sheet for airing the fumigated stack at the end of exposure period was accomplished with the help of ropes and pulleys. These were found to reduce the cost of fumigation treatment considerably, on account of least use of gas mask canisters.

The prevention of cross-infestation was carried out by a formulation containing Lindane, and using Dutrex (batching oil used by the textile industry), jute batching oil, vegetable oils like groundnut, coconut, sesame and linseed as carriers. This could offer a residual effect for 4 months with a deposit of 50 mg of lindane per sq.ft. which is not possible by dust formulations of the pesticide under tropical conditions. Where longer residual effect than 4 months was required a similar high viscosity oil based formulation of DDT and Lindane was used.

Knapsack type sprayer with a low volume nozzle attachment was used for spraying on the peripheral aspects of the stacks at the rate of 2-2.3 ml. per sq.ft.

Assessment of infiltration of droplets through the weave clearance of different sacking materials such as A-twill, B-twill, D.W. and Heavy coes (Table-7) have indicated that there was no risk of contaminating granular products by spraying the high viscosity formulation on the peripheral aspects of the bag stacks of sacking materials containing up to 26% weave clearance 13. But sacks having higher weave clearances

cannot be directly treated by spraying with the formulation in view of the danger of contaminating the stored commodity with the pesticides. It has been observed that milled materials and the stocks held in bags of high weave clearances can safely be provided with suitable prophylactic covers. Old sacking materials stitched in the form of a sheet and sprayed with the high viscosity oil based formulation could prevent cross-infestation quite effectively over such stocks when used as a cover.

Typical results of the large-scale trials with different commodities under warehouse conditions are given in Tables 4 & 8.

Conclusions::

Results of the experiments described in the paper have indicated the following:

- i) Incorporation of EDB in MB improved its insecticidal effect (Table-1) and helped in maintaining more uniform concentrations at all layers of the commodity under fumigation (Table-2).
- ii) At 100° F and above beneficial effects of EDB-MB combinations were very conspicuous both in the fumigation trials carried out in columns and gas-proof sheets. (Tables 2 and 3).
- iii) Permanent residues in the foodstuffs were comparatively less with mixture than methyl bromide alone (Tables 4 & 8).
- iv) Operational safety was greater with the mixture than MB alone or MB with 2% chloropicrin, as EDB could carry both MB and Chloropicrin in dissolved state to the exit points.⁶
- v) The fumigation process when accompanied by a prophylactic spray treatment could ensure insect free conditions of the commodity for longer duration. (Tables 5 & 8).
- vi) High viscosity and non-volatile oils remarkably increased the persistence and insecticidal potency of all the insecticides tested (Table-6) as compared to low viscosity oils, and water dispersible formulations. Use of the insecticide treated cloth over the fumigated stack for preventing cross-infestation was found to be very safe, effective and practical (Tables-7 & 8.).

These results could be extended to bagged commodities under warehouse conditions and also small packages in retailers' shops. Wide ranges of commodities could be treated under varied conditions by adjusting the proportions of EDB and MB according to the chemical composition of the products, package size and material, warehouse conditions and atmospheric temperature.

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TABLE - 1

Doses* required for 99% mortality at 25°C, 44 hrs exposure.

Fumi- gant	<u>Tribolium</u> <u>castaneum</u>	<u>Calandra</u> <u>oryzae</u>	<u>Aræcerus</u> <u>fasciculatus</u>	<u>Stegobium</u> <u>paniceum</u>	<u>Rhizo-</u> <u>pertha</u> <u>dominica</u>	<u>Oryzae-</u> <u>philus</u> <u>surina-</u> <u>mensis</u>
EDB	2.5	3.6	2.5	9.6	9.3	4.8
MB	15.0	6.7	4.5	10.0	8.3	10.2
EDB+ MB (1:1)	3.4	2.5	3.6	4.5	3.4	3.0

* nominal mg/l

TABLE - 2

Studies on the stratification of EDB and MB in mixture
through Jowar and semolina columns(5')

Fumigant		Temp.	Jowar**		Semolina †	
%		oF	C x T	Mortality %	C x T	Mortality %
EDB	MB		mg.hr/litre	<u>T.castaneu</u>	mg.hr/litre	<u>T.castaneum</u>
100	0	68(20°C)	36	0	0	0
		100(37.8°C)	67	21	22	0
75	25	68	74	34	25	0
		100	104	60	79	23
50	50	68	98	100	223	100
		100	242	100	208	100

(Cond.)

1	2	3	4	5	6	7
25	75	68 100	263 206	100 100	218 195	100 87
0	100	68 100	288 179	100 100	220 93	100 34

C x T = Concentration-time product of the mixture.

+ = nominal dose 32 mg/litre.

= nominal dose 48 mg/litre.

Mortality and C x T at the end of 48 hrs. at bottom sampling point.

TABLE - 3

Fumigation of wheat flour under gas-proof sheets

Fumigant		Maximum Temperature during fumigation. °C	Dosage lbs/1000 ft ³ for 48 hrs.	Percent mortality, <u>T. castaneum</u> adults		
EDB	MB %			Top	Middle	Bottom
0	100	23	3.0	100	100	100
		30	2.5	56	68	74
		41*	3.0	23	21	18
25	75	30	2.5	100	100	100
		41	2.5	100	100	100
33	67	30	2.5	100	96	85
		41	2.5	100	100	100

* Within 15 minutes after administration of MB, the gas-proof sheet became inflated considerably due to high pressure.

- with bags
with chemical
Res., 1955, 14, 298-232.
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Insect proofing of jute bags for grain storage.
Research in Industry, 1955, 6, 391-395

TABLE - 1

Doses* required for 99% mortality at 35°C. 44 hrs exposure.

Fumi- gant	<u>Tribolium</u> <u>castaneum</u>	<u>Calandra</u> <u>orboris</u>	<u>Anagasta</u> <u>fusculipes</u>	<u>Stegobium</u> <u>paniceum</u>	<u>Rhizo-</u> <u>pertha</u> <u>dominica</u>	<u>Coryae-</u> <u>philus</u> <u>surina-</u> <u>monsis</u>
EDB	2.5	3.6	2.5	2.6	9.3	4.8
MB	15.0	1.7		10.	8.3	10.2
EDB+ MB (1:1)	7.2	2.5	2.1	1.5	3.4	3.0

* nominal mg/l

TABLE - 2

Studies on the effectiveness of EDB and MB in mixture
through Jowar and semolina columns (3')

Fumigant		Temp. °C	Jowar +		Semolina +	
%		°F	Conc. mg/hr./litre	Mortality %	Conc. T	Mortality %
EDB	MB			T. castaneum	mg.hr./litre	T. castaneum
100	0	68 (20°C)	36	0	0	0
		100 (37.5°C)	67	21	22	0
75	25	68	74	3	25	0
		100	104	0	29	23
50	50		98	100	223	100
				100	208	100

(Contd.)

- TABLE-4

PILOT-SCALE SEMI-COMMERCIAL EXPERIMENTS WITH EDB+MB
MIXTURES UNDER DIFFERENT CONDITIONS

Commodity	Temp	Capacity cu.ft.	Insect species	Dosage 1b/1000 cu.ft. EDB MB	Mortality	Bro- mide residue
Enriched wheat flour in polyethylene lined bags	27-30	6,200 (godown)	<u>T.castaneum</u>	1.0 1.6	Total	17
Wheat flour	23-26	1,320 (godown)	<u>T.castaneum</u>	0.8 2.2	"	8
	30-41	960 (Rubberised sheet)	<u>T.castaneum</u> <u>E.cautella</u>	0.8 2.2	"	11
Green gram	23-26	2,000 (PVC sheet)	<u>B.chinensis</u>	1.9 0.6	"	3
Rice	23-26	2,000 (PVC sheet)	<u>C.oryzae</u>	1.9 0.6	"	6
	28-33	630 (Rubberised fabric)	<u>O.surinamensis</u> <u>C.cephalonica</u>	1.0 1.0	"	7
Monsooned	30-33	3,000 (Rubberised fabric)	<u>A.fascicu- latus</u>	0.75 0.75 0.00 1.5	"	14 23
Peanut	25-27	9,200 (godown)	<u>E.cautella</u>	0.5 1.5	"	20
		218 (Fumigation valult)	<u>T.castaneum</u> <u>T.granarium</u> <u>C.oryzae</u> <u>E.cautella</u>	1.0 1.0	"	13
Dried peas	23-25	1,890 (godown)	<u>B.chinensis</u>			
Tur dhal			<u>T.granarium</u> <u>C.oryzae</u>	1.3 0.7	"	5
Bengal gram dhal	25-28	9,200 (godown)	<u>B.chinensis</u> <u>T.granarium</u> <u>C.oryzae</u>	1.0 1.0	"	5
			<u>T.Castaneum</u> <u>E.cautella</u>			
Indian Multi- purpose food (seasoned)	26-29	218 (Fumigation valut)	<u>S.paniceum</u>	0.6 1.4 0.0 2.0	"	34 53

(Contd.)

1	2	3	4	5		
Copra	29-31	648 (PVC sheet)	<u>N.rufipes</u>	0.0	2.0	" 35
			<u>A.piceous</u>	0.5	1.5	" 16
			<u>Carpophilus</u>			
Tapioca macaroni	26-27	218 (Fumigation valut)	<u>C.oryzae</u>	0.6	1.4	" 6
Tapioca flour	126-27	218 (Fumigation valut)	<u>T.casta neum</u>	0.0	2.0	" 11

TABLE -5

Penetration of pests of stored foods through fabrics
and films Temp. 22-26°C and R.H. 36-68%

	C.o	T.c.	B.c.	S.p.	R.d.	A.f.	E.c.	C.c	P.a
Nylon fine mesh	0	0	-	-	A	0	0	-	A
Cotton mull	A	-	-	A	A	A	0	-	A
A-twill	0	0	-	-	A	-	0	0	-
Jute A-twill	A 0	A 0	A 0	-	A	A 0	0	0	-
B-twill	A 0	A	A 0	A 0	A	A 0	0	0	-
D.W.	A 0	A	A 0	A 0	A	A 0	0	0	-
Heavy cress	A 0	A	A 0	A 0	A	A 0	0	0	-
Hessian	A 0	A	A 0	A 0	A	A 0	0	0	-
Polyethylene									
100 g	A 0	A 0	0	A 0	A	0	0	-	A
200 g	A 0	A	0	A)	A	-	-	-	A
300 g	A 0	A	-	-	A	-	-	-	A
400 g	A 0	-	-	-	A	-	-	-	A
700 g	- 0	-	-	-	-	-	-	-	A
Kraft paper	A	A 0	-	0	A	-	-	-	A
Cellophane	- 0	A 0	-	0	A	-	0	-	A

A = penetrated by adult
O = oviposition

- = not infiltrated

A.f. = raecorus fasciculatus
P.a = Periplaneta americana.

C.o = Calandra oryzae

T.c = Tribolium casta-
neum

B.c = Bruchus chinensis

C.c = Corcyra cephalonica

S.p. = Stegobium paniceum

R.d. = Rhizopertha dominica

E.c. = Ephestia cautella

TABLE-6

Effect of carriers of insecticides on the persistence and insecticidal potencies.

Carrier/ oil	LD ₉₅ (T.cast. Exp.30 mins.) mg/sq.ft.	Persistence on glass surface after 100 days, (%)*		
		BHC Tech	DDT	Malathion
Dutrex-3	46	8.9	1.9	60.3
Groundnut	39	8.7	0.8	66.2
Castor	52	9.8	0.9	63.2
Linseed	78	12.4	1.8	68.3
Sesame	61	9.4	2.0	67.0
S.E 10	133	16.6	2.8	64.5
Batching oil	115	14.3	2.2	62.3
Kerosine	137	37.4	2.4	39.8
Xylene	139	38.2	2.3	37.2

* Percent of original deposit.

TABLE-7

Lindane infiltration through fabrics
(50 mg/sq.ft.intial application on the surface)

Formulation	Viscosity (Redwoods No.1(sacs))	Drop size (microns)	Fabrics, mg/sq.ft.			
			twill	B twill	D.W.	Hessian
1. Kerosine, acetone xylene.	39	1-60	0	2	6	29
2. Batching oil Dutrex, Ground- nut oil	171	15-320	0	0	1	12
Weave clearance and infiltration time through fabrics for <u>C.oryzae</u> .						
Weave clearance %			3	6	21	68
Infiltration time, mins.			90	45	30	5

TABLE - 8

EFFECT OF THE PROPHYLACTIC CLOTH ON THE STORAGE OF
FUMIGATED SORGHUM AND COFFEE AFTER 4 MONTHS OF STORAGE

Stack	Fumigant & Dosage (lb/1000 c.ft)	Prophylactic cloth (applied) (mg/sq)	Br. residue (ppm) Top Bottom	Living insect count No./100g	Frass (g/100g)	K.D. (%)
		Lindane DDT				
<u>Sorghum</u>						
I	EDB+MB(1:1) 51.5	0	0 5 7	0	0	0
II	EDB+MB(1:1) 1.5	50	50 56 8	0	0	0
III	MB 1.0	0	0 8 11	198	2	14
IV	MB 1.0	50	50 7 11	9	slight	1
V	MB 2.0	50	50 8 12	0	0	0
VI	Control 0.0	0	0 - -	321	4	21
<u>Monsooned coffee beans</u>						
VII	EDB+MB 2.0	0	0 7 18	24	1	5
VIII	EDB+MB 2.0	50	0 9 23	0	0	0
IX	MB 2.0	50	0 8 39	0	0	0
X	Control 0.0	0	0 0 0	536	25	92

K.D. = Kernel damage

NV/
6-5-66

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE, MYSORE

DUROFUME PROCESS:

Instructions for fumigating with Ethylene Dibromide
and Methyl bromide mixtures.

I. GODOWNS

1. Make a thorough inspection of the godown with emphasis on the following points.

(a) Whether the building can be made air tight, with reference to windows, ventilators, sky-lights, doors, drainage holes, and rat-burrows or tunnels, if any. All these have to be sealed or plugged properly. Quite often some bag stacks are laid against doors, windows etc., hiding the presence of such structures. Hence an inspection of the outside of the godown has to be made to detect hidden doors and windows to avoid a leak of the gas. In addition all possible information about the structural details of the godown should be collected from the godown keeper.

(b) Buildings having both godown and residential quarters: Extreme caution should be exercised when fumigating such places. There may be wooden partition or a door separating the godown from the occupied quarters. If there is any doubt regarding achieving an air tight condition with regard to these, either the people should be made to vacate the premises for a specified time (not less than 7 days) or godown fumigation has to be given up. Cover fumigation may be attempted here, if possible. It is needless to stress here that the cover should be in perfect condition and not leaky. Storeyed structures may have the top storey above the godown inhabited, the sealing of the godown being the flooring of the storey. This may be made up of jointed wooden planks or if terraced may have creaks and crevices in the plastering work and at the junction of the wall and the sealing, reapers and the wall, etc. All such openings should be sealed, if possible from both sides.

(c) Type of commodity and total number of bags; if possible also the tonnage should be noted.

(d) Calculation of the godown capacity in cubic feet. This can be obtained by multiplying the length, breadth and the height of the godown. Extent of occupied space and the unoccupied space can be obtained by taking as 1000 cu.ft. for every 200 bags of grain. This subtracted from the total capacity will give the amount of unoccupied space.

(e) Degree of infestation and the insect species present should also be noted. A high degree of infestation especially of Tribolium sp. needs a higher dosage or a longer exposure period. Trogoderma the Khapra beetle needs special consideration for fixing the dosage of any fumigant. In the Southern States of U.S.A. and Mexico, -

4-5 lb/1000 cu.ft. methyl bromide has been applied. Durofume 1:1 (EDB: MB), 2-2.5 lb/1000 cu.ft. has been found to be adequate against Trogo-
derma infestation.

(f) Grain samples should be drawn from all the types of commodities and labelled with the following details:

- i) Name of Godown
- ii) Date of fumigation
- iii) Commodities- whether infested or not
- iv) Exposure period and date of opening godown
- v) Effect of fumigation on mortality of insects (if living insects are present these should be collected and kept with food for observation to see whether they die later).
- vi) Samples drawn from each stock before and after fumigation should be incubated to see whether the immature stages such as eggs, larva and pupa are killed or not.

Follow the PROFORMA for DUROFUME PROCESS and keep detailed record for each fumigation.

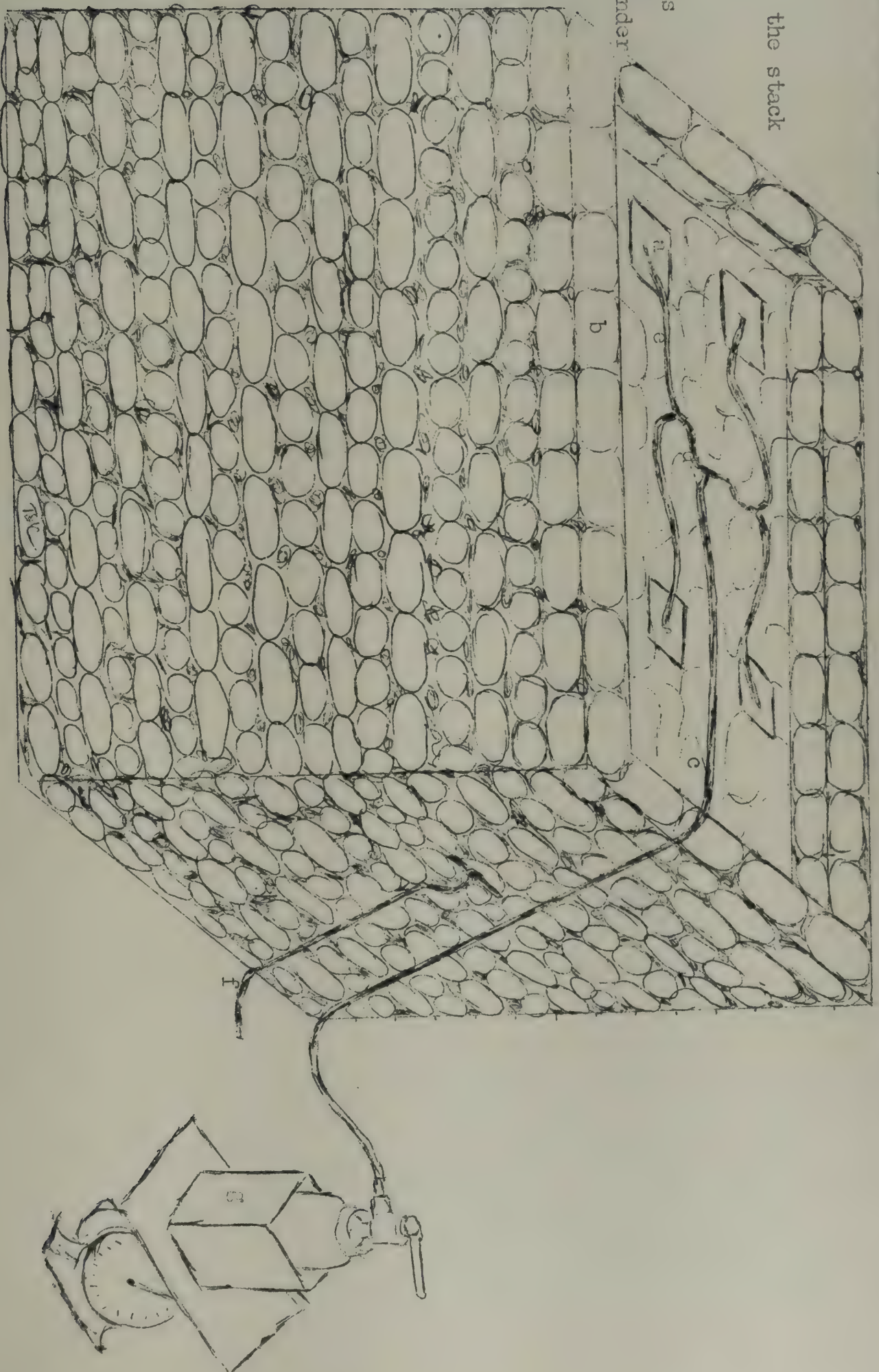
2. Preparing the godown for fumigation:

a) Kraft paper strips should be pasted against all joints and crevices in the woodwork, drainage holes, etc. Where paper and gun will not stick, a flour putty or mud plaster should be used to plug them tight. All possible sealings from inside should be finished first leaving only the exit door, so that after coming out this can be pasted and sealed from outside. Sealing Tapes for fumigation as developed by the CFIRI may be prepared and used whenever required. It can be used over and over again. The sealing tape can be prepared by coating a layer of Bees wax-Petroleum jelly mixture 3:1 or 4:1 (w/w) on cloth tape. If the atmospheric temperature is lower than 25°C proportion of petroleum jelly should be increased to make the mixture softer. Two sizes, 5" width and 3" width, are required generally, for sealing the junctions of two fumigation sheets and bottom seams.

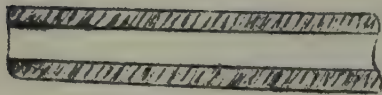
b) Laying out the tubing: As many fumigation points as warranted by the godown capacity can be had; 7 x 7' formula for distance between points may be applied. Rubber pressure tubing or polyethylene tubing will be suitable for distribution inside the godown, but the fumigant inlet tubing lying outside the godown should necessarily be of rubber pressure tubing or flexible copper tubing and NEVER polyethylene (low density and high pressure) tubing or soft rubber tubing as these may start leaking after sometime. "T" joints of hard glass or copper can be used for making connections for distribution of the fumigant exit points. The exit points should lie always on the top portion of the stacks. The ends may be firmly secured by a thread to prevent the tubes slipping down. While securing the tubing care should be taken not to pinch the tube itself as this may choke the passage of the fumigant and may result in accidents due to bursting of tubes. If the stack is too large the main tubing should be increased in number using 4 to 5 discharge (exit) points for each one. The gunny cloth

Stack with arrangement of tubes for fumition with the gas proof cover removed to show details

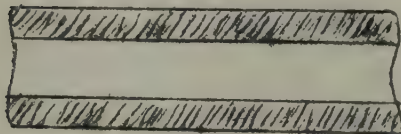
- a) Vapourisers
- b) Depression in the stack
- c) Main
- d) Secondary
- e) Tertiary
- f) Probe with gas sampling tube
- g) Fumizant cylinder



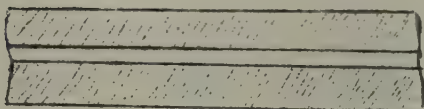
DUROFUME PROCESS - ACCESSORIES



Main
pressure tubing $1/4"$ i.d. c.



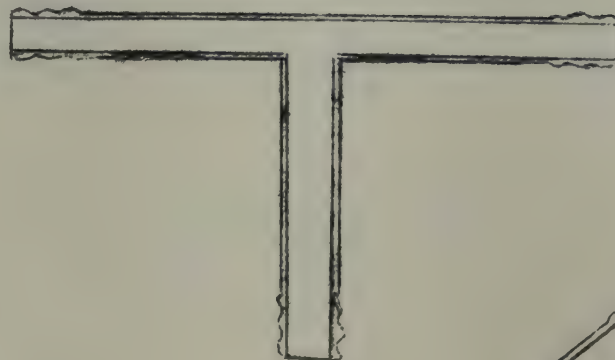
Secondary $1/8"$ bore



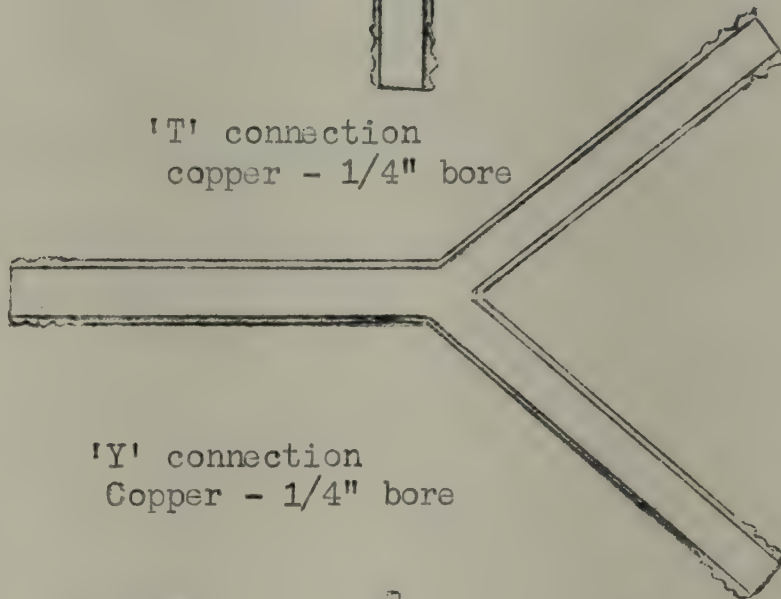
Tertiary
 $1/16"$ bore



Capillary - 2 mm bore



'T' connection
copper - $1/4"$ bore



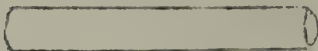
'Y' connection
Copper - $1/4"$ bore



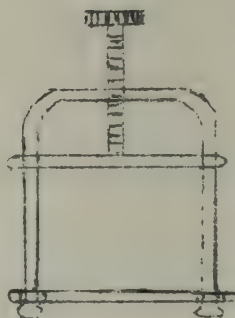
Straight connection
copper - $1/4"$ bore



Hose clamp $5/8"$ and $3/4"$



Pinch cock



spread over the stack for DUROBASE treatment acts as a spreader for the fumigant from the point of introduction of DUROFUME. At each discharge point, one 'fumigant vapouriser' should be placed for soaking the fumigant. The vapouriser 3' x 4' mounted on frame gives rigidity. Gunny bags A-twill or B-twill or D.W. types can be selected for stretching on the frames.

For retaining methyl bromide for adequate period at the top along with ethylene dibromide and avoiding too quick stratification the terms of one bag depth should be created prior to placing the fumigant vapouriser at the top of the stack.

The main trunk, secondary branch and tertiary branch terminating in suitable orifice should be in conformity with the flow of fumigant through the nozzle of the cylinder. For the $6\frac{1}{2}$ lb. cylinders having the adapters the following dimensions of the mains, branches and terminal orifices have been found satisfactory:

- | | |
|----------------------------|---|
| 1. Main tube | O.D. $\frac{1}{2}$ "
I.D. $\frac{3}{16}$ " |
| 2. Secondary polyethylene | O.D. $\frac{5}{16}$ " or $\frac{1}{2}$ "
I.D. $\frac{3}{16}$ " |
| 3. Discharge point orifice | Diameter $\frac{1}{8}$ "
O.D. $\frac{1}{4}$ "
I.D. $\frac{1}{8}$ " |
| 4. Y-joints and T-joints: | Limb 1.5"
I.D. $\frac{3}{16}$ " or $\frac{1}{4}$ "
O.D. $\frac{1}{4}$ " or $\frac{5}{16}$ " |
| Bulged points: | O.D. $\frac{5}{16}$ " (to give grip) |

The tube to the gas cylinder (rubber pressure tubing with thick walls) should be drawn out of the godown through a small hole (preferably of the same diameter as the tubing) bored in the door or use can be made of existing holes, if any. Often one of the bolts and nuts fastened to a padlock can be temporarily removed and the tube passed through this. There should be good metal pinch-cock about 4" from the opening, so that after the fumigant has been administered, the pinch-cock can be screwed tight and left in position. A solid metal or glass rod should be thrust in the tubing inlet after removal from the nozzle of the cylinder. Remove the hose clamp and fit it to the next main inlet tubing.

c) Test insects in sample tubes plugged with cotton wool/cloth mesh or wire gauge can be placed at as many points as possible. Preferably some may be left inside a bag for noting the mortality of insects in the deeper layers. Probes of suitable construction can be employed for placing the test insect at various depths and locations. Care should be taken to allow the diffusion of fumigant freely at the point of insertion.

d) Before starting the fumigation operation place a gasproof sheet over the stack and drape it over, but do not seal at the floor. This will cover the fumigant dosing cistern (tank) and prevent the free movement of the fumigant up and diffusion to the empty space. The fumigant is guided to travel through the stack. Penetration through the stack and distribution of fumigant to achieve the required concentration for sufficient period will be facilitated by this simple technique. Efficiency of godown fumigation method is increased for disinfection of the commodities held in the godowns. Two to three film vapourisers should be placed in the empty space at a height near the roof so as to have the space, roof and wall disinfection. Dosage for free space, may be at $\frac{1}{4}$ - $\frac{1}{2}$ lb./1000 cu.ft., while for the stack a dosage of $1\frac{1}{2}$ lb. of 1:1 should be given for grains. For milled articles and oil seeds, 1:2 or 1:3 mixture Durofume should be applied.

3. The fumigation operation: Before the final sealing of the godown for fumigation make sure that all the unwanted equipment is taken outside and nothing is left inside such as foot-wear, extra-tubing, gas-masks, spray equipment, etc. Switch off lights, if any. Drive out pests like cats, dogs etc., which may have gone inside without our knowledge. Make sure that everybody is outside the godown and apply the finishing touches before releasing the fumigant.

At this point it is necessary to review the preparations made with reference to aeration or degassing. Arrangement for opening ventilators, windows or doors from outside should be made as far as possible.

Now check up the tubing system for absence of blocking or obstruction with compressed air from a knapsack sprayer after removing the nozzle and inserting to the MAIN tube prior to connecting to the cylinder or applicator.

The mixtures of ethylene dibromide and methyl bromide can be administered from cylinders or the applicators designed by the CFTRI.

The pressure inside a cylinder containing ethylene dibromide and methyl bromide mixture is lower than methyl bromide cylinder. Usually leakage can be detected easily due to the presence of ethylene dibromide. The cylinder should be kept in a holder or secured properly and dropping and violent heating should be avoided.

The hood enclosing the valve assembly of the cylinder containing appropriate proportion of ethylene dibromide and methyl bromide now be unscrewed and the valve where the spindle key fits is oiled well with the bolt still closing the fumigant outlet on the cylinder, the valve head should be eased by slight opening and closing immediately (the valve opens if turned in the anti-clockwise direction and closes if turned in the clock-wise direction). Violent hitting to open valve should never be attempted. This may damage the whole assembly or result in serious accidents if there develops any crack. Enough oil at the valve head always helps in easing the valve for smooth action. Now, the valve being in the closed position, the bolt guarding

the exit hole should be unscrewed in open air away from persons and the adaptor having a nozzle screwed in its position fairly tight but not too tight. If it is screwed very tight the washer inside the adaptor may spread and choke the exit hole. Now the pressure tubing coming out of the godown can be pushed over the nozzle as far inside as possible. A $\frac{1}{4}$ " hoseclamp may be screwed at the base of the tubing around the nozzle as a further safeguard against the tubing slipping out while the fumigant is flowing under pressure.

The cylinder may now be placed on a platform balance or any other suitable balance and held in a vertical position. This can be also done by inverting a stool over the platform and placing the cylinder inside it. The initial weight of the cylinder may be noted and the valve opened slightly to release gas. By placing the tube against the ear or with the aid of a stethoscope the flow of gas can also be heard. The valve may be opened more and more if assured that all the connections are firmly fixed and that there is no possibility of leaks through loose fitting of tube at the nozzle or a puncture or a crack in the tubing due to constant use. This can be ascertained by having at hand a halide detector lamp. A green flame shows up a leak in the system or in the godown. When the desired quantity of the fumigant has gone in after noting the loss in weight, the valve can be closed turning it in the clock-wise direction. The pinch-cock on the tubing can be tightened fully. The tube can now be slipped off after unscrewing the clamp which is holding in position the tube on the nozzle. The tubings may be scavenged by flushing with air from a compressed knapsac sprayer pump. Close the pinch cock and plug the end with a solid metal or glass rod. A GAS MASK SHOULD BE WORN BY THE OPERATOR OR OPERATORS DURING THE ENTIRE OPERATION. The CFTRI gas-mask for Durofume fumigation is cheap and efficient and does not require importation, from foreign country and can be constructed easily by trained operators. Old canisters also can be used after revivification.

In case the tube slips off the nozzle due to high pressure cracks or tears developing, the valve should be closed immediately. To facilitate this the spindle-key should be in place on the valve head during the entire operation. No unauthorised person or persons should remain near the operation area. The place should be as airy as possible; open air if in shade can be made use of for keeping the cylinder while in operation with a good length of pressure tubing between the godown and the cylinder.

Some foreign firms supply Methyl bromide in cylinder after pressurizing it heavily. These are meant for fumigation at low temperatures. Do not use these methyl bromide cylinders in tropical countries.

At the end of the operation a placard with the following warnings preferably in the local language should be pasted on the door front (BOLD LETTERS).

DANGER

POISON GAS

PLEASE KEEP OFF

Instructions should be left with the man in charge of the godown NOT to open the godown under any circumstances. The godown should be opened by the fumigation personnel only.

Always remember ACCIDENTS DO NOT HAPPEN THEY ARE CAUSED.

4. Opening the godown for aeration:

All the fumigation personnel should be equipped with gas masks before attempting to open the godown. A halide lamp should be burning. The main entrance door may be opened full and left open for not less than 4 hours before attempting to open the windows, ventilators, etc. The halide lamp whenever required should be placed in full view from outside and away from the grain bags. No one including the fumigation operator should enter inside the godown while the flame shows a green colour or shades of green. This will indicate as to when a safe concentration is reached and when it is safe to enter. A clear flame without any tinge of green denotes this. While closing the godown for the night the windows and ventilators should be left open to assist aeration. The godown keeper should be instructed to keep the godown doors open one hour each day before working the godown, even after the fumigation is over, at least for one full week. Corresponding samples to the ones drawn before fumigation should be drawn and left labelled for observation later. The tubing can be removed quickly after six hours of aeration on the opening day of the godown wearing gas masks or the next day.

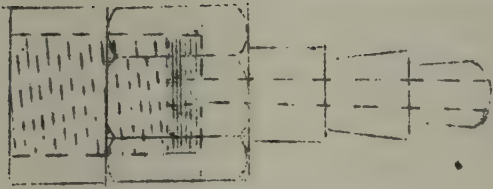
If proper planning is done for aeration from outside gas mask canister need not be spent.

II. FUMIGATION UNDER COVERS

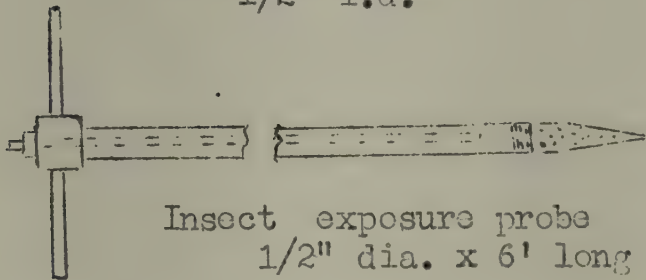
When it is not possible to undertake godown fumigation, fumigation under a gasproof cover can be practiced.

Procedure: The stock has to be measured and the volume noted (L x B x H). The tubes for the fumigant are laid and distributed in the same fashion as in a godown. If the stacks lie against walls on one or two sides the sheet is covered over the stack, the edges about 6" wide being paste against the walls with kraft paper strips to form an air tight seal. A few nails may be driven securing the edges to the walls firmly to avoid the cover or sheet slipping down; a couple of sand bags may be used as weights on top of the cover. The free edges on the ground should be sealed with mud or sealing tape and weighed down by placing sandbags. 4" x 4" wooden bars may be placed on the margin of the fumigation cover to weigh it down on the floor. At places weight may be used on the wooden bars or battens. If the stack is having free-sides alround the edges touching the ground should be sealed all around. No weight should be placed on the portion housing the inlet tube of the fumigant. The inlet tubing should be long enough to place the DUROFUM FUMIGANT APPLICATOR or cylinder away from the margin of the stack, it is preferable to draw as far as the

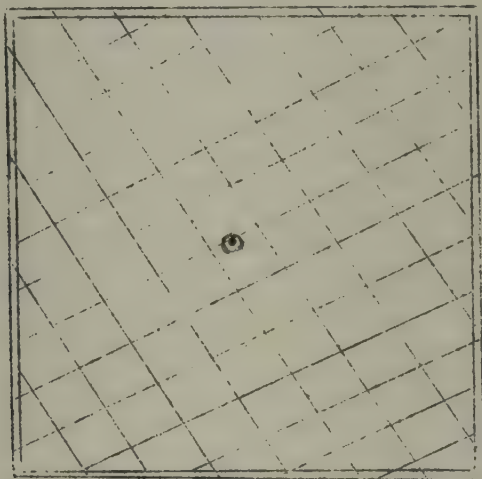
DUROFUME PROCESS :: ACCESSORIES (contd)



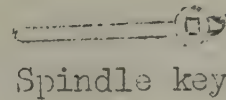
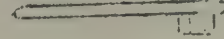
Cylinder nozzle
1/2" i.d.



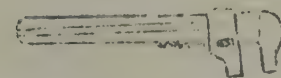
Insect exposure probe
1/2" dia. x 6' long



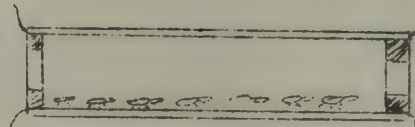
Gunny vapouriser 2' x 2'



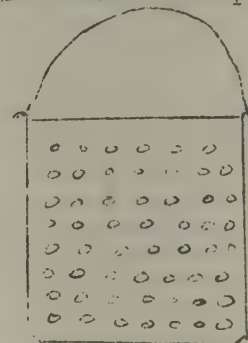
Spindle key



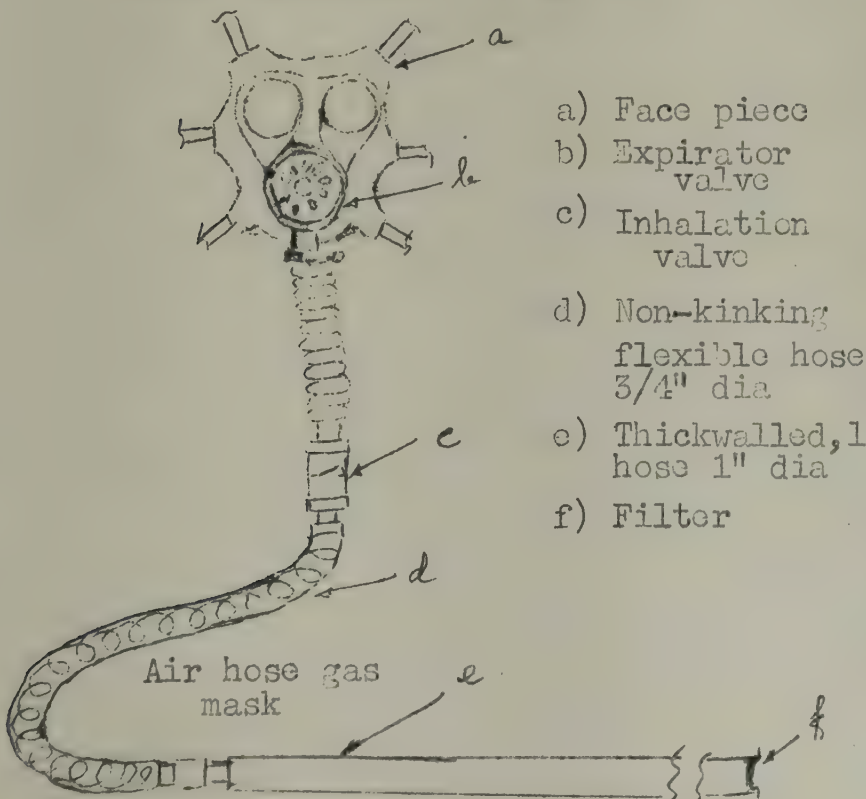
Adjustable screw spanner



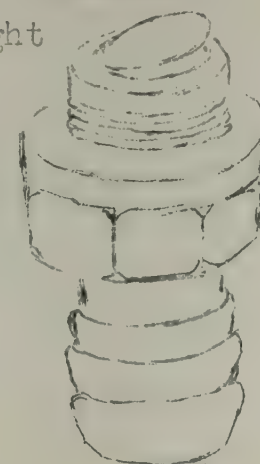
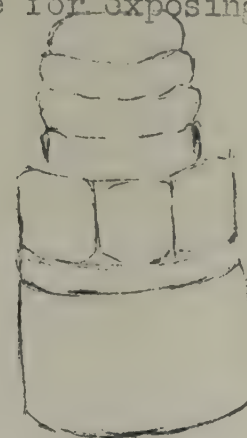
Test insect exposure tube



Cage for exposing insects in space

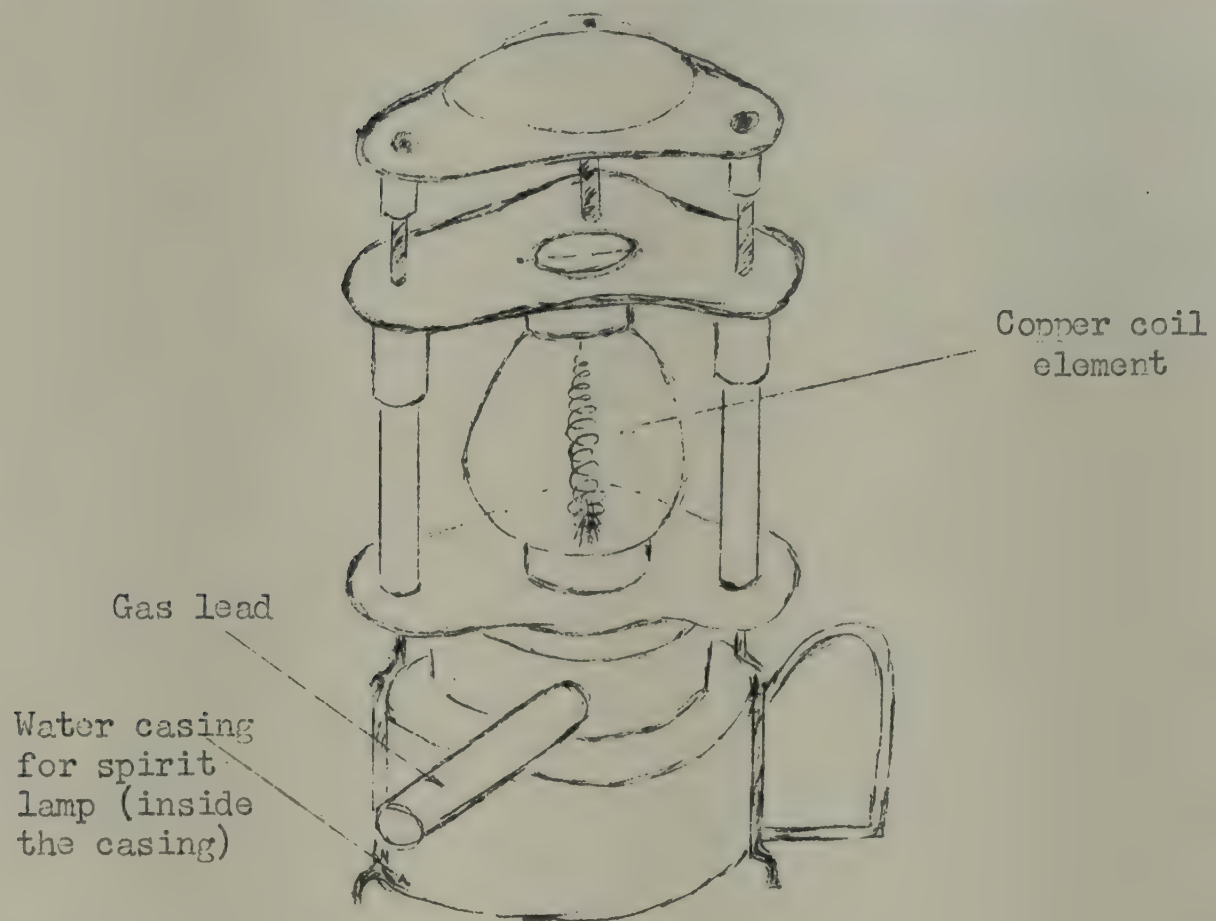


- a) Face piece
- b) Expirator valve
- c) Inhalation valve
- d) Non-kinking flexible hose 3/4" dia
- e) Thickwalled, light hose 1" dia
- f) Filter

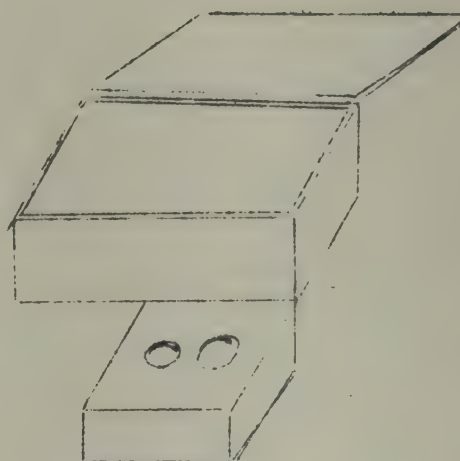
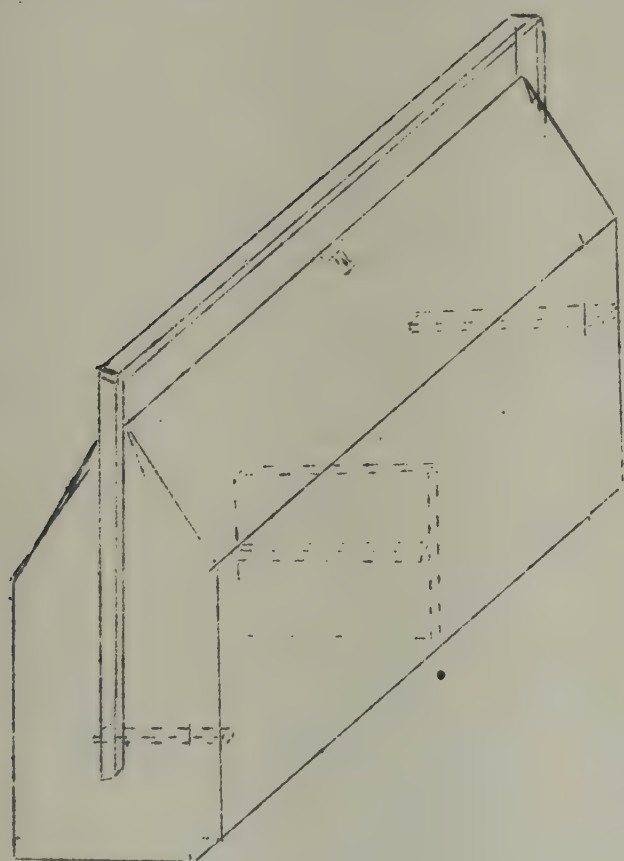


(a) enlarged

HALIDE LEAK DETECTOR



BK



DUOFUME PROCESS SET
BOX NO. III

entrance door of the godown. Fumigant should be introduced keeping the doors open. Ensure the sealing of the cover to remain in position inspite of gusts of wind.

Inspection of the gas-proof sheet should be thorough before using for fumigation. All tears however small they may be should be sealed. This can be done efficiently by bringing the cover to the open ground and lifting it up sufficiently to enable one person to get in and observe light leaks. This will show, damage, if any, in the cover sufficient for all practical purposes. These leaks can be patched up with adhesive tapes or patches with rubber solution for gluing. After thoroughly going over the entire area of the sheeting and having satisfied that no leaks are left unattended the sheet can be commissioned for fumigation. Before each fumigation a routine inspection of the cover is absolutely necessary. This fact if overlooked may prove DANGEROUS. The other fumigation operations are similar to that of a godown fumigation. On the day of the lifting of the cover all the precautions observed while opening a fumigated godowns should be followed strictly. The cover should be lifted halfway and draped over the stack exposing the front portion as well as a portion of the top. In godowns where trusses and rafters are present these can be used profitably for placing the fumigation cover on the stack/lifting the cover for aeration of the stack after the exposure period, with the help of pulleys and strings. The sandsnakes and other materials used for giving weight on the fumigation cover seam should be removed before manipulating the strings for lifting the cover. If an adequate distance is maintained from the stack under fumigation at the time of lifting the cover a considerable saving of the gas mask canister can be made. After a lapse of 4 hours or more the cover can be lifted completely. Allthrough the operation gas-masks should be worn and the halide detection lamp employed for noting fumigant concentration. The remote control with rope or string for opening the cover from outside will always be profitable. For safety one long air-hose connected to the gas mask should be kept at hand which may be used when the gas mask canisters get exhausted and spare one is not available at hand.

TECHNIQUES FOR ASSESSMENT OF THE FUMIGANT CONCENTRATION AND PROCESS CONTROL DURING FUMIGATION.

Thermal conductivity units for fumigant analysis are available but these are to be imported. At the C.F.T.R.I. some easy techniques have been developed for the process control even under warehouse conditions. The principles of the techniques are based on bioassay, flame test, chemical analytical procedure. Test insects - Tribolium castaneum (red flour beetle) adults are placed in a U-tube with arrangement for closing the arms. By using an aspirator bottle or rubber bulb pump air sample is drawn in the tube (Insect exposure tube) containing the test insects and the stoppers or pinch-cocks are closed. The effect of the gas sample drawn from the godown on mortality time of the insects are noted. If the death of the insects is cent per cent during the exposure period, it can be taken for granted that the fumigation is successful.

The flame test with a sensitive halide leak detector lamp can also be carried out on air samples drawn through the heated copper wire at either a specified rate or utilizing the suction developed in the hood (chimney) of the lamp. The lead tube of halide detector connected with the sampling point in the fumigated chamber/warehouse/tent will draw the air sample by the suction developed in the heated chimney. If required drawing of the air sample can be done by operating a squeeze bulb pump in between the lamp and the sampling tube. Colour and intensity of the flame will indicate the approximate concentration of the fumigant in the air sample drawn from the sampling point.

Other assay technique for the Durofume fumigant is based on dehydrobromination of ethylene dibromide and methyl bromide by monoethanolamine. This chemoassay technique has been described in the publication entitled "Hydrolysis of ethylene dibromide by monoethanolamine at ordinary temperatures," Jour.Sci.Indust., Res. Vol. 19-B, pp. 273-274, (1960).

Standard equipment like Thermal Conductivity units and Riken gas detectors are available in many countries, which could be used by firms who could afford such units.

It has been possible to apply either one or all the techniques stated above under practical fumigation conditions and the result of fumigation could be predicted in time. This has been extremely useful in detecting faults if any in advance and rectify the same in time with no additional expenditure.

If the fumigant concentration is below the thresh-hold level of 2 mg./litre at any point and bioassay shows incomplete mortality of test insect. The sealing of the sheet on the ground and any other leakage point should be detected and rectified. A fresh charge of some quantities of the fumigant may be applied in the stock or the area under fumigation.

Durofume applicator: The applicator for EDB and MB mixtures consists of fumigant reservoir for EDB, feeding line to the applicator tube, a scaffolding to house MB can, a device of puncturing the can with a probe, a dip tube inside the tubular container for EDB and a discharge nozzle connected to the main fumigation line (vide Res.&Ind. Vol.7, No.7, 237-239, 1962.)

Operation: Ethylene dibromide is gravity fed into the horizontal applicator tube through the middle nozzle using a graduated aspirator as the ethylene dibromide reservoir and a pressure tubing connecting the two. Only requisite quantity of ethylene dibromide (209 ml./lb.) should be filled each time. The filling is best done while the applicator is already connected to the fumigant inlet tubing from the godown or gas-proof sheeted stack. After the required quantity of ethylene dibromide has entered the container, the tube is disconnected and closed by means of a short piece of rubber tubing with a pinch cock.

DUROFUME CAN APPLICATOR

Nozzle for discharge
5 mm i.d., 35 mm long.

Scaffold for can
173 x 89 x 26

Press plate
76 dia

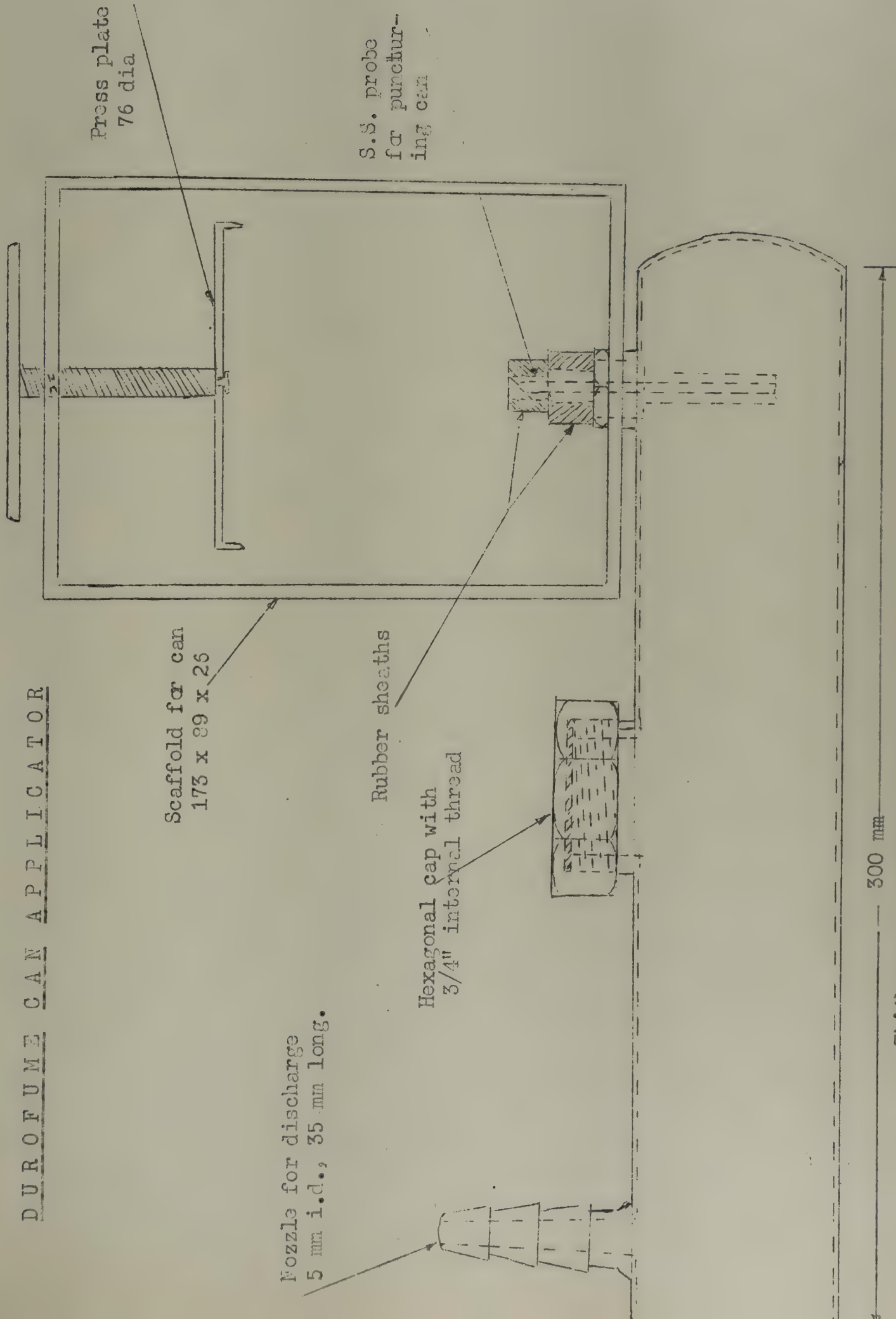
S.S. probe
for punctur-
ing can

Rubber sheaths

Hexagonal cap with
3/4" internal thread

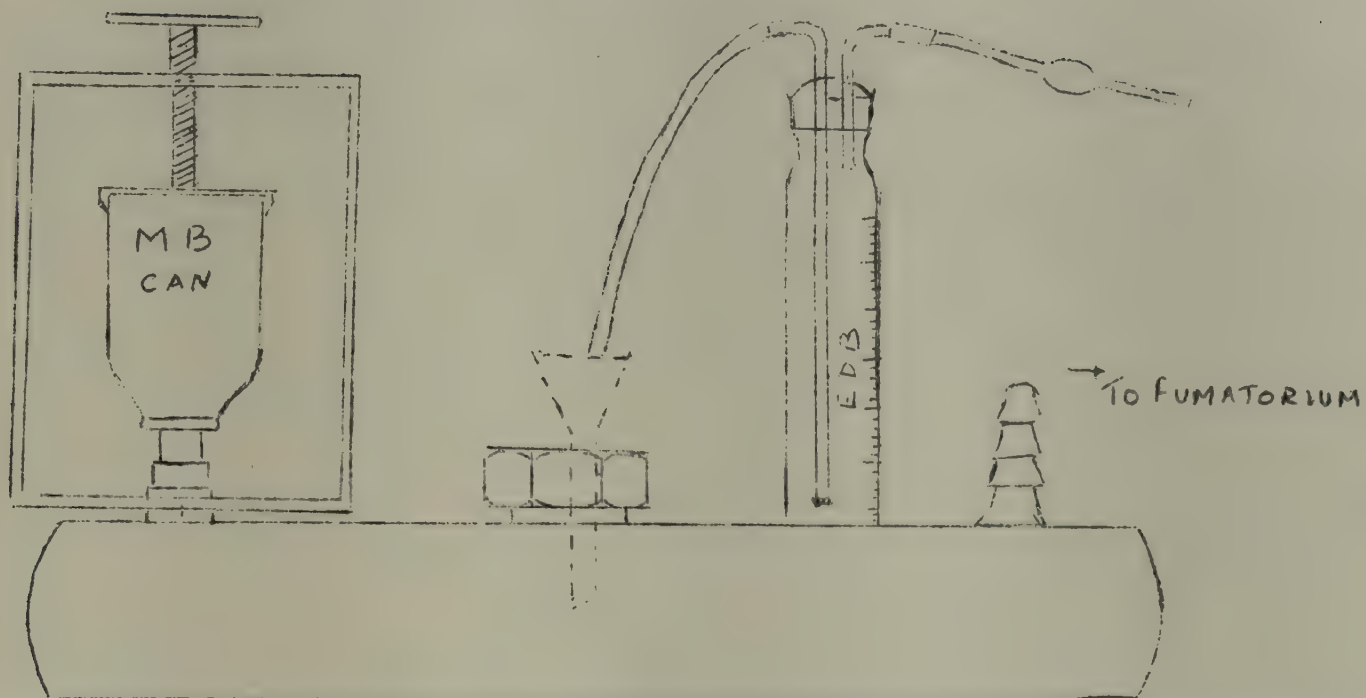
300 mm

Thickness of metal: 4 mm "

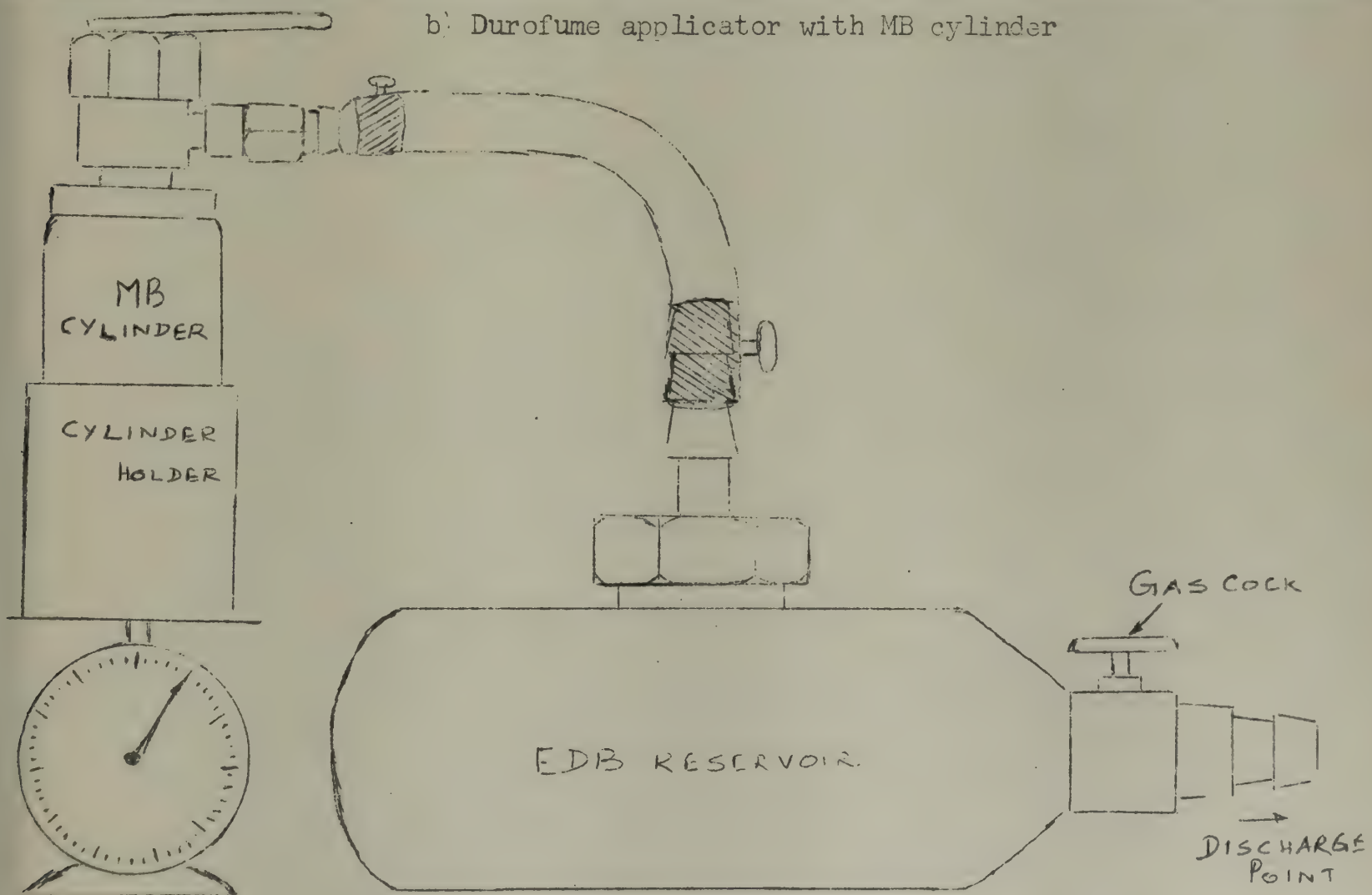


DETAILS OF CONNECTIONS

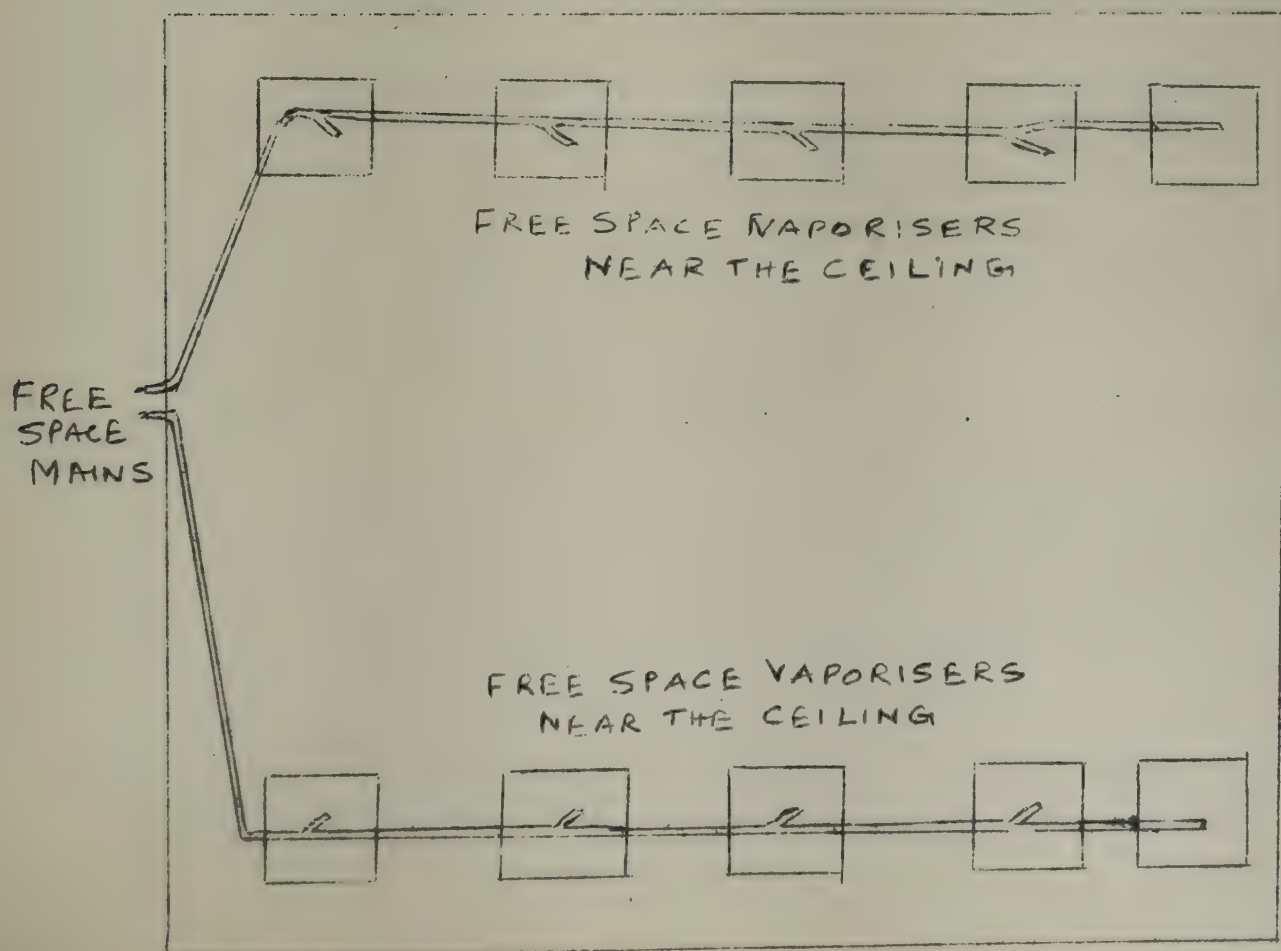
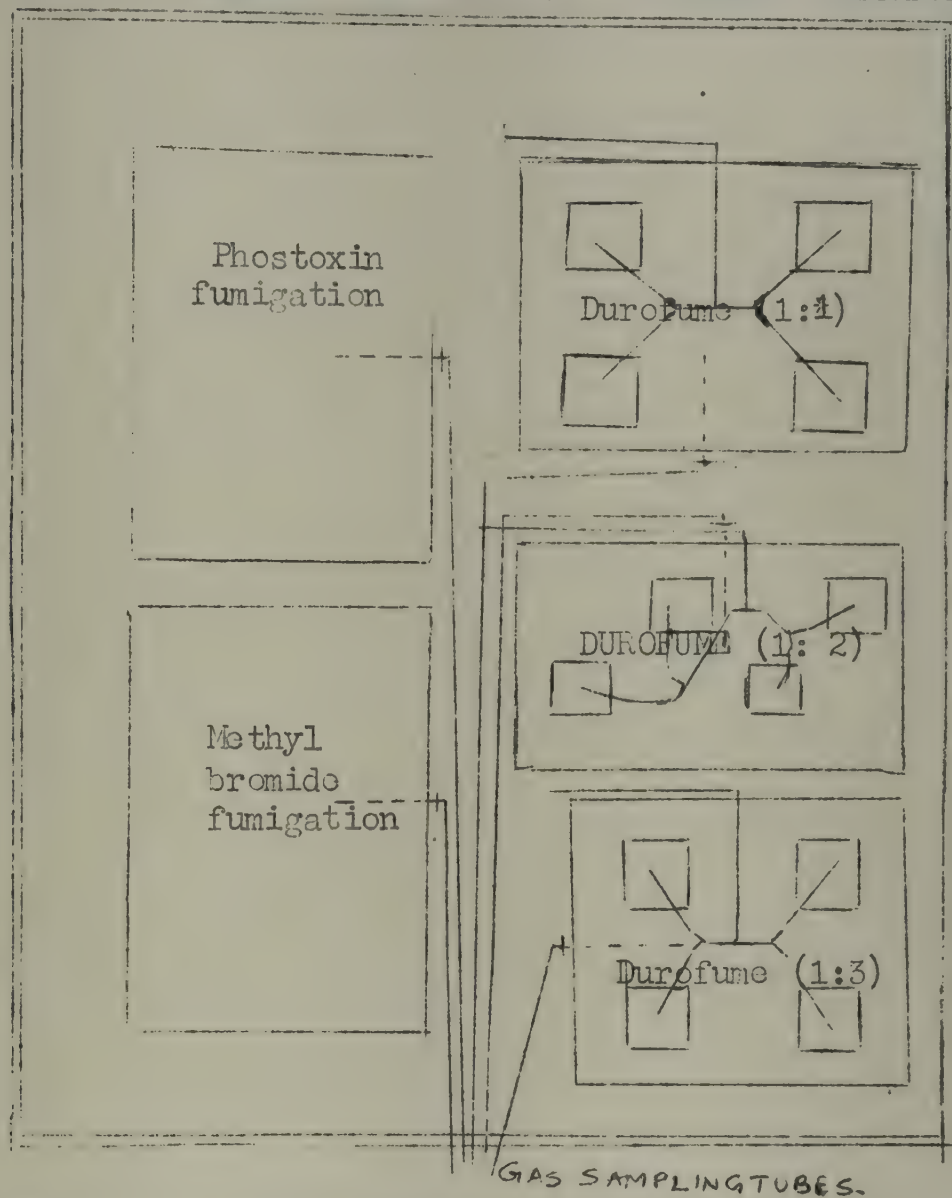
a) Durofume can applicator



b) Durofume applicator with MB cylinder



MULTIPLE FUMIGATION
PLAN OF GODOWN WITH STACKS OF DIFFERENT COMMODITIES



An one lb. can of methyl bromide is inserted into the scaffold and the platform is turned slowly till the probe rubber sheath makes contact with the can. After making sure that the connections are well secured and aligned the platform is moved further. A slight resistance is felt on the handle of the drive indicating that the probe has made contact with the metal of the can top. A couple of turns more will pierce the can and the methyl bromide flows into the applicator. Methyl bromide dissolves in ethylene dibromide at the temperature of application (solubility at 25°C., 20%). At this point the discharge point of the applicator should be held in an inclined position towards the flow direction to facilitate the pumping of the liquid ethylene dibromide by the pressure of methyl bromide. Initially the flow of the fumigant is fast as liquid methyl bromide flows into the horizontal container. But in the later stages when the level of methyl bromide falls below the probe point, methyl bromide is discharged only by evaporation in the gaseous form. To empty the can completely it takes about 6 min. at room temperatures (25-27°C). After the fumigants are exhausted, the inlet tube can be disengaged and plugged suitably and the applicator left in the open for half an hour to air off any residual vapours of the fumigants.

By using 'T' and 'Y' joints and placing the discharge nozzles of the distributor at 6 ft. apart an equitable distribution of the fumigants at different points of the stack can be obtained. Fixing capillary tubes (of 2 mm. bore) at the discharge ends on film-evaporators, which are 3 x 2 ft. or 3' x 4' wooden frames with stretched gunny hessian, helps in getting required rates of vapourization and building up of atmospheric and intergranular concentration of the fumigants in the warehouse and under gas-proof sheets.

Lay the tubing, vaporisers, discharge points on the stacks and empty space (if free space of the godown is to be fumigated) keeping in view the dosage and proportion required for each stack and commodity. Apply the desired proportion of the Durofume mixture through each lead tube. The CFTRI Multiple Fumigation Technique can easily be followed by using the applicator with MB can or MB cylinder. T or Y junction with stop-cock connections for each main lead tube can be used and manipulated for discharging, the applicator partly in one and rest in other as may be required under some situations especially while fumigating some small stacks.

III. SOME PRECAUTIONS FOR FUMIGATION

1. Unless the godown can be made air-tight do not undertake godown fumigation. Fumigation should be carried out only under a gas-proof tent (Rubberised fabric or PVC fabric or balloon cloth). Polyethylene (low density) covers are not suitable for fumigation under Indian conditions of climate.

2. Fumigant cylinder should be placed outside the door of the godown in free airy place while releasing the fumigant inside the godown.

3. Even while carrying out fumigation under tent the length of the tubing should be sufficient to draw and place the fumigant cylinder in the airy place.

4. Do not release the fumigant cylinder within the godown, place it outside the godown in free airy place and administer the fumigant through the suitable length. Remember that any time the cylinder adaptor is removed from the tubing (inlet), both cylinder valve and inlet tube should be closed.

5. Always fumigate a godown where the adjoining rooms are vacated and not used for residential purposes. Even, if there is first floor in which it is being used for residential purposes, do not fumigate the ground floor unless the top floor is vacated.

6. Do not fumigate a stack of more than 200 bags, until the operators get enough practice and exercise to fumigate a bigger lot. Godown fumigation should only be adopted wherever good air-tight godowns are available.

7. When the required exposure period is over aerate the godown thoroughly. First open the entrance door, keep it open for four hours, they only attempt to go in and open the other doors and windows. It is preferable to open the ventilator doors and windows from outside. The remote control device for lifting the tents will be extremely helpful. Although all the operators would wear the gas masks for these, they should not go inside the godown immediately after opening or in high concentration of fumigant in the atmosphere.

8. Even when the clearance certificate is given on sufficient aeration of the godown, the godown keeper or his staff should always keep the entrance doors wide open for at least 1 hour/precautionary measure.

9. In addition to the gas mask canisters long hose (light rubberised hose) non-collapsible type should be kept with operators for use for drawing air from distance.

10. Please remember that skin also absorbs some quantities of fumigant if exposed to high concentration. Even if one wears respirator canister one should not remain in the environment having high gas (fumigant) concentrations.

11. Never take anything for granted, inspect everything. (i) the tent (fumigation cover) (ii) the tubing sizes, fitting lengths (iii) Respirators and canisters (Martine "antigas" canisters are useless) and also the fitting of air hose type (iv) godowns premises, etc.

12. Check up your list of items before, starting any fumigation job.

13. Repair the tents (covers) thoroughly, if there is any

damaged spot or punctures and check the tubings, nozzles, adaptors, pumps for any clogging, etc.

14. Do not over strain, because fumigation operators should be alert, intelligent, and steady while in job.

15. After fumigation do not forget to desorb the fumigation sheet before folding and flush the tubing with air.

16. Read (1) the precautions given by the manufacturers of the fumigants, (2) fumigation with methyl bromide precautionary measures, U.K., Home Office, (3) Methyl bromide Fumigation under G sproof sheets H.M.Stationery Officer, U.K.

IV. INSTRUCTIONS FOR APPLICATION OF DUROBASE

There are three DUROBASE Spray formulations:

- a) One for termite control - Durobase I
- b) one for prophylactic treatment of stack and warehouse against insects - Durobase II.
- c) one for the insect-proofing and rodentproofing of stacks and warehouses Durobase III.

The special features of Durobase formulations are high degree of persistence on treated surface and great toxicity to insects at low dosages of pesticides. No volatile solvent which can be absorbed by grain and give the residue problem as is true with kerosene and volatile solvent carriers in formulations.

1. Examine the stock, bags and godown to cover all the exposed or spilled grains. The torn bags, may either be replaced with sound bags by replacement or turning sides, or be stitched. DO NOT SPRAY ON EXPOSED GRAINS.

2. Examine the type of bag. If the bags are closely woven, direct spray may be adopted with the DUROBASE. The bags which are not closely woven should not be sprayed directly. Empty old gunny bags may be opened and stitched together in the form of a sheet (tarpaulin). Spray the DUROBASE and put it as a cover over the stack (Durobase treated prophylactic gunny cloth). Standard samples of gunny fabrics will serve as guide, for deciding on the type of spray treatment to be adopted.

3. USE THE SPRAYER WITH THE SPECIFIED NOZZLE. KEEP THE PRESSURE FULL IN THE HAND COMPRESSION OR THE ROCKER SPRAYER, WHILE LOW PRESSURE GIVES COARSE SPRAY AND WETS THE FABRIC. Spray with the recommended pressure to give fine spray at the rate of 2 ml./sq.ft. This level will not wet the bags. It is essential to spray by maintaining high pressure in the SPRAYERS.

4. Calculate the exposed surface area of the stack and transfer

measured quantity of Durobase in the pump. Bring the pressure full by pumping before releasing the valve of the nozzle. Keep the pressure high by intermittent working of the piston.

5. It is always safe to spray on the bag surface keeping the nozzle axis in inclined (at an angle) position than to spray perpendicularly to the surface to be sprayed.

6. In some sample gunny bags, filter paper may be placed below the fabric and the bag stitched with the grain. The filter paper may be examined after spraying for the degree of contamination, if any, from bags placed at different position of the stack.

7. Do not forget to take samples of grains, both before and after the treatments.

8. Markings to detect pilferage and undesirable manipulation of the stack will be advantageous.

9. Take all extra precautions for avoiding contamination of the spray on the grains, on body parts and skin.

10. One person in each team should specialise and become skilled DUROBASE spray operator, who should do the job personally.

11. Smoking and taking food should be avoided during working in godown. After the work, washing of the protective clothings, hands, etc., with soap and water is essential.

12. DO NOT TRANSFER THE "DUROBASE" WITHIN THE GODOWN BECAUSE THE LIQUID MAY BE SPILLED ON THE FLOOR AND MATERIAL MAY GET SOAKED IN THE SPILLED LIQUID. TRANSFER THE LIQUID FROM CONTAINERS TO SPRAYER ONLY OUTSIDE THE GODOWN.

13. DO NOT STORE THE CHEMICALS WITHIN A GODOWN CONTAINING GRAIN BAGS. STORE AWAY FROM FOOD ARTICLES.

14. KEEP A WATCH ON THE CONTAINERS - IF THERE IS ANY LEAKAGE TRANSFER TO A SOUND CONTAINER.

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE

LIST OF EQUIPMENT FOR DUROFUME PROCESS

DUROFUME PROCESS SET -BOX NO.1

1. Durofume Cylinder - 2.5 kg. capacity
2. Methyl Bromide 1 lb. cans in Box
3. Durobase-3 in tin - $\frac{1}{4}$ Gallon
4. Ethylenedibromide in tin - 2 Kgs.

I TRAY

5. Durofume Applicator
6. Spare rubber sheath for applicator (in small box)
7. EDB measuring jar (polythene) with graduations
8. Adjustable screw spanner

II TRAY

9. Screw driver
10. Balance
11. Spindle key for cylinder
12. Adaptor nozzle for cylinder
13. Pinch cock and hose clamp

III TRAY

14. Distribution tube 1 set with spare tubings
15. Box containing spare connections, glass rods etc.
16. Low volume nozzle durobase sprayer 1 as per spec.
17. Cylinder holder
18. Low volume nozzle: 1 as per spec.

DUROFUME PROCESS SET-BOX NO.2

18. Sand snakes
19. Gunny vapourisers
20. Adhesive tape (small roll)
21. Small piece of gas proof sheet for patch-work
22. Adhesive cement
23. Danger signal board
24. Apron and hand gloves
25. Needle and thread

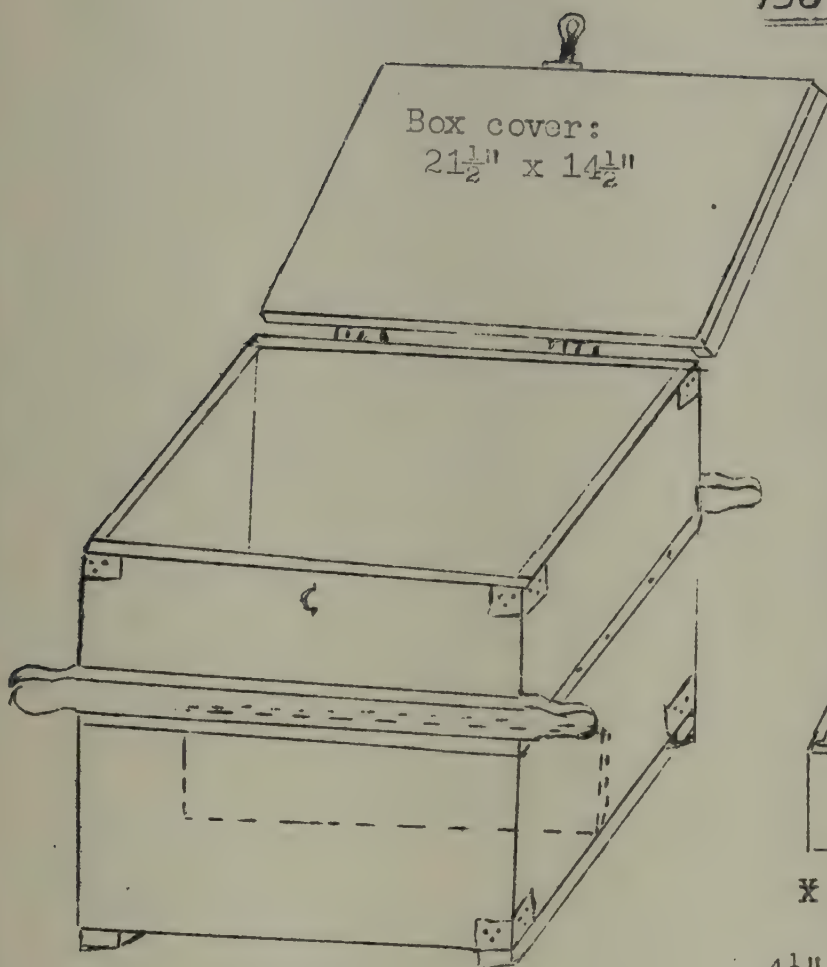
DUROFUME PROCESS SET-BOX NO.3

26. Halide leak detector lamp
27. Spare chimney and copper coil
28. Gas mask
29. Spare canister for gas mask
30. Nose mask with goggles
31. Grain sampler
33. Polythene bags and labels.

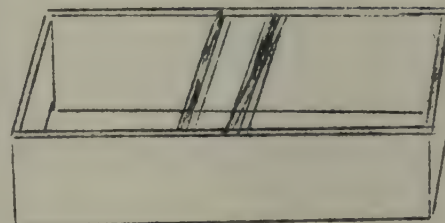
DUROFUME PROCESS SET-BOX No.4 for Gasproof Sheet

DUROFUME PROCESS SET

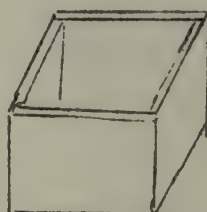
Box No I



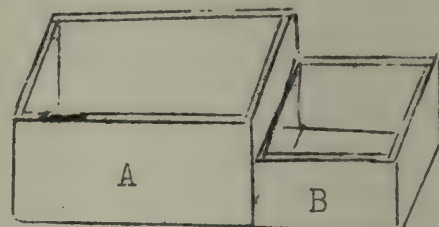
Box for
MB cans
 $5\frac{3}{4}" \times 5\frac{3}{4}" \times 4\frac{7}{8}"$



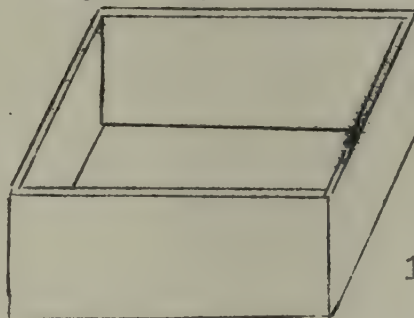
Tray I
 $18\frac{3}{4}" \times 5\frac{1}{2}" \times 4\frac{1}{4}"$



* Cylinder
Holder
 $4\frac{1}{2}" \times 4\frac{1}{2}" \times 4\frac{1}{2}"$



Tray II
A. $12\frac{1}{2}" \times 5" \times 4"$
B. $6" \times 5" \times 1"$



Tray III
 $13\frac{1}{4}" \times 12" \times 5\frac{1}{4}"$

Main box

Internal dimensions:

$20" \times 13" \times 16\frac{1}{2}"$

Partition: $20" \times 6" \times \frac{3}{4}"$

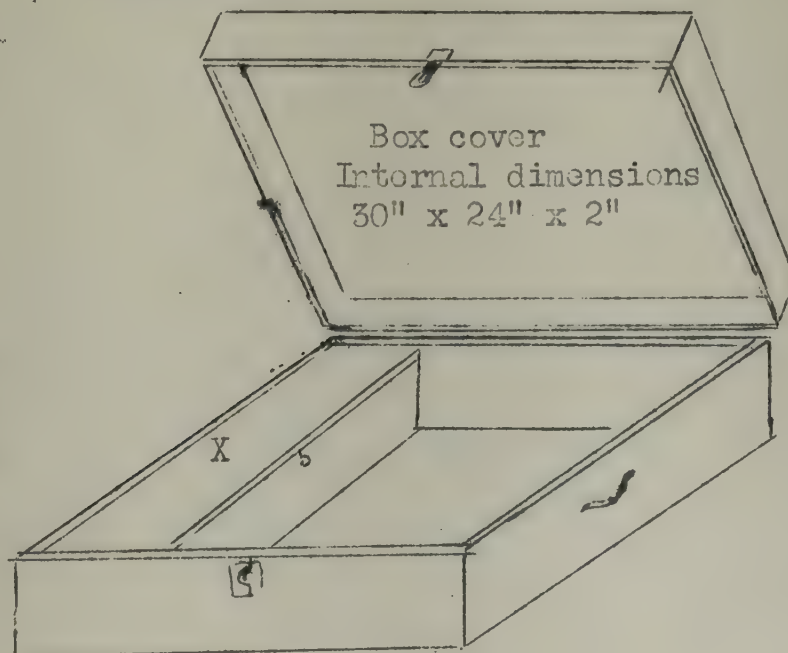
Dimensions pertain to internal
dimensions

Wood thickness:

for main box: $\frac{3}{4}"$

for trays etc.: $\frac{1}{2}"$

Box No II



Box: $24" \times 24" \times 4"$

Wood thickness: $\frac{3}{4}"$

X: Compartment with lid on
hinges

$24" \times 5\frac{1}{2}" \times 4"$

V. LIST OF EQUIPMENT FOR FUMIGATION UNDER GAS PROOF SHEET IN NOT AIR TIGHT GODOWNS

Items	Specification	Suppliers (in India)	Quantity & Size	Remarks
1	2	4	5	6
Fumigation sheets	PVC (Polyvinyl coated fabric) (aluminium coated) or Rubberised fabric (aluminium coated) or Balloon cloth	1. Bhor Industries, Bombay 2. Eastern India water Proofing Co. Calcutta 3. Infestation Control Corp., Bangalore 5 4. Verma Indust. B'lore.	64' x 55'	Size and number should depend on the size of the stacks built and No. of fumigations to be carried out every day.
Pressure tubing	Good quality rubber tubing O.D. $\frac{1}{2}$ " I.D. $\frac{3}{16}$ "	Travancore Rubber Works	250'	After each fumiga- tion flushing with air will increase the life. Polyethy- lene high pressure low density not suitable for use. PVC tubing can be used.
Rubber tubing	O.D. $\frac{1}{4}$ " I.D. $\frac{1}{8}$ "	-do-	100'	-do-
Finch cock	Screw type	Locally	8 Nos.	
Hose clips	$\frac{1}{4}$ " x $\frac{1}{2}$ " each, screw type, adjustable	Locally	12 Nos.	
Pulley and cotton rope	4" dia. pulley	Locally	8 Nos.	
Polished iron rod	3/16" dia. - 2 $\frac{1}{2}$ " long	Locally	6 Nos.	
Balance Spring	Salter scale - 0-10 kg.	Avery & Co.	1 No.	
Gas mask with canister	25 gms. graduation Purotha suitable for methyl- bromide or Gaspro type	Burn & Co.	2 Nos.	

1	2	3	4	5
Gas mask Halide leak detector	Airhose type Lamp Tiley or a prototype	Burn & Co. or Locally Blue-Star, Voltas, Air Conditioning & Refri- gerators, Ltd., Gody, Alwin & Co.	1 Nos. 2 units	Efficient & cheap. The temp. and gauze of copper mesh or spiral govern the sensitivity.
Adjustable Spanner Fumigant vapouriser	2'x2' of A-twill/DW fabric stretched by a cross reaper	Locally Locally made	One 10 Nos.	Extremely useful item increases the vaporisa- tion rate. Precaution to be taken to aerate before carrying in closed van after fumi- gation.
Durefume Applicator	As described	<u>Res. & Ind.</u> 7, 391-393, 1962.	2 Nos.	Can be used with MB cans and also cylinders. Pro- portions of EDB:MB can be suitably adjusted. Extremely useful in Multiple Fumigation by DUROFUME PROCESS.
Cylinder Key Screw Driver, Adopter	For methyl bromide $\frac{1}{2}$ ", $\frac{1}{4}$ ", $\frac{1}{8}$ " for fitting to the outlet stub of the cylinder 3/8" male thread. The outlet end to fit with the delivery hose (3/16" dia.)	May & Baker	Two 1 each 2 Nos.	Adopter must be with correct fitting tread & washer should not cover or choke the cylinder nozzle.
or T joints	Limb 1.5" I.D. 3/16" or $\frac{1}{4}$ " O.D. $\frac{1}{4}$ " or 5/16" with grip (bulged point o.d. 5/16")	Locally	20 Nos.	Hose clips should be fitted so that the tubings do not slip off. Should be suitable for spraying high viscosity fluid and should not atomize to mist or very small particles.
Livee Sprayer with lance & low volume nozzle		Burmah-Shell & Co.	One	

1	2	3	4	5
Utility Sprayer hose, lance & Low volume nozzle		Addison & Co.	One	Should be suitable for spraying high viscosity fluid and should not atomize to mist or very small particles.
Marut hand com- ½ gallon low volume nozzle.	Sprayer	American Spring & Pressure Works	1 No.	-do- (as in 'Utility Sprayer hose)
Hand gloves (rubber) gauntlet type	Solventproof	Local purchase	1 doz.	After use soap washing, drying and dusting with talc are essential.
Overall Coveralls	Plastic with cloth lining; Clean, non-shatter type	-do- Burn & Co., Joseph Leslie, Indian Oxygen Co.	2 Nos. 2 pairs.	-do-
Mouth piece IUDOFIX (a) adhe- sive plaster cords, (b) strings, ropes Durofume cylinders	Dust filter type a) 1" b) 1½" 6½ lb. Units	Locally prepared Local purchase :- Purchase from CFTRI	2 Nos. a) 1 Roll b) 1 roll as required	
Measuring cylin- der	1 litre capacity	From any Sci. supplies	One	
Measuring tape	50-100 ft. length	Locally	One	
Funnel (Stainless steel or glass)	4" dia.	Locally	Two	
Sealing Wax Tape	5" and 3" width	Locally	400 ft.	
FIRST AID KIT			One	
Bio & CHEMO ASSAY KIT	For Durofume and Durobase	Assembled	One unit	

PROFORMA FOR DUCOFUME FUMIGATION

A. GODOWN FUMIGATION:

1. Person in-charge of fumigation.
2. Names of personnel operating.
3. Date of fumigation
4. Place/works/Premises
5. Particulars of godown:

a) Godown No. & Address/Location.

b) Dimensions of the godowns.

Length:ft.

Breadth:ft.

Height: ft.

Volume; ft.

c) No. of doors, windows, drainage holes, crevices or any other outlets.

d) Nature of roofing - tiled or terraced or panelled with planks

e) Whether any crevices are observed in the walls, floor and roofing.

f) Any special remark on the godown/structure

6. Particulars of grain/commodity taken up for fumigation:

a) Type and grade

b) Lot/ Bulk. Nos.

c) No. of bags of each type and grade.

d) Total quantity of each type and grade.

7. Volume occupied by the stack in the godown: Cu.ft.

Volume occupied by the empty space in
the godown

Cu.ft.

Layout of bag stacks with details.

8. Fumigants required for fumigation, proportion, etc.

9. a) Quantity of fumigant required for fumigating the stack.
@ lbs. for 1000 Cu.ft.

b) Quantity of fumigant required for fumigating the empty space.
@ lbs. for 1000 Cu.ft.

Total

10. Whether proper planning has been made and considerations given to
 - (i) the manipulation of ventilators, windows, doors, etc., from outside to facilitate aeration.
 - (ii) Lifting of fumigation sheet or cover spread as false roofing, if used for non-airtight roof using pulleys.
11. (a) Whether the main tubes and secondaries have been tested for easy flow of the fumigant.
 - (b) No. of mains used with 'windows' and their length.
 - (c) No. of secondaries with 'windows' and their length.
 - (d) No. of 'T's and 'Y's used.
 - (e) Whether the mains and secondaries have been properly fixed and placed in position.
 - (f) Whether the ends of the secondaries have been placed on the 'fumigant vaporiser'.
 - (g) Whether arrangements have been made for protecting the mains and bottom sealing from rats.
12. Whether the required No. of samples of all types and grades of commodities have been drawn and labels fixed on the containers?
13. Whether numbered insect-exposure-tubes with live insects have been inserted into the bags and placed in the stack at convenient positions and such bags marked?
14. a) Time at which sealing/pasting was started.
 - b) Whether all the doors, windows, ventilators, outlets, etc.
 - c) Whether it was ensured that all persons in the godown have come out and all the articles brought out of the godown and then locked and sealed
 - d) Time at which the sealing was completed and the total time taken for making the godown air-tight.
 - e) Recorded the materials used/consumed for preparation.
15. Whether it has been ensured that persons other than the fumigation personnel with the gas-masks on, are in the vicinity of the godown.
16. Whether the gas mask with canister tested has been commissioned for use and work properly.
17. (a) Whether the valve of the cylinder has been tested with the spindle key for easy operation with the bolt in position?
 - (b) Whether the bolt has been removed and the nozzle fixed and tightened with the hose clamp; and placing the screw type pinch cock in position?
 - (c) Initial reading of the balance with the spindle key.
 - (d) Pinch cock examined and kept open.
 - (e) Time at which the fumigant was released.
 - (f) Whether it was tested and ascertained that there were no leakage of the fumigant?
 - (g) Final reading of the balance.
 - (h) Quantity of fumigant used.
 - (i) Period for which the fumigant was discharged.
 - (j) Whether the valve of the cylinder has been closed tightly with the spindle key?

- (k) Whether the pinch cock was tightened and the main tube attached to the hand compressor and air blown after loosening the pinch cock for flushing the fumigant in the tubing system?
 - (l) Whether the pinch cock was again tightened and the opening of the main tube fixed with a solid metal (or glass) rod?
 - (m) Whether the nozzle was replaced by screwing the bolt tight and the hood closed?
 - (n) Whether the main tube has been secured and placed in a safe position?
 - (o) Whether the quantity of the fumigant used was noted on the cylinder card?
 - (p) Whether the period for which the canister was used was noted on the canister card with remark on the exposure to fumigant, if any.
 - (q) Whether leak detector was used, colour of the flame noted.
- 18. Whether a warning signal noting thereon the date and time of fumigation has been put up conspicuously on the door?
 - 19. Whether proper instructions were issued to the watchman of the godown?
 - 20. Whether periodical inspections were conducted to ensure that the arrangement was not disturbed?

AERATION OF THE FUMIGATED GODOWN

Person in-charge:

- 1. No. and address of the godown fumigated.
- 2. Date and time of fumigation.
- 3. Time and date on which aeration was taken up.
- 4. If an interval of less than 48 hours was allowed, the period so allowed and the reasons thereof.
- 5. Whether it was ensured that no person other than the aeration personnel with the gas mask on, was present in the vicinity of the godown?
- 6. Whether it was tested with the leak detector wearing gas mask on that there were no leakages of the fumigant and that the arrangement was not disturbed?
- 7. Whether the windows and ventilators were opened from the outside wherever possible?
- 8. Whether the door was opened and the halide lamp, placed near the door to observe concentration of the fumigant?
- 9. Period for which high concentration was observed.
- 10. Whether an entry was then made with gas mask on into the godown and the paper strips, etc., torn out to facilitate greater aeration?
- 11. Time at which the aeration was complete and no trace of the fumigant found inside or outside the godown.
- 12. Whether insect exposure tubes were collected and mortality observed. Counted to recover all the exposure tubes, placed in the stack.

13. Whether all the tubings, etc., were removed and exposed in the open for aeration and flushing with compressed air carried out?
14. Whether sufficient number of samples (at least 4 Nos.) were drawn and one sample each sent to CFTRI for residue analysis, etc., with the detail particulars of treatment?
Particulars: a) Sample drawn before fumigation
b) Sample drawn after fumigation
15. Whether all the tubings, covers, etc., were removed and laid in the open for aeration before packing and carrying those?
16. Whether instructions were issued to the watchman of the godown not to allow any person inside the godown for one hour after opening the godown every day, for a week?
17. Whether the warning signal was taken off and a clearance certificate issued?
18. Whether the period for which the canister was used was noted on the canister card and the mask placed in suitable container separately and stored away from fumigant containers, covers and tubings.

B. COVER FUMIGATION:

1. Person in-charge of fumigation
2. Names of persons operating
3. Date of fumigation
4. Place/works
5. Particulars of the godown and stack:
 - a) Godown No. and address where the commodity is stacked
 - b) Type and grade of grain/commodity stacked
 - c) Bulk/lot Nos.
 - d) No. of bags of each type and grade and quantity.
 - e) Dimensions of the stack:
Length: ft; Width: ft; Height: ft;

Cubic capacity:
6. Fumigant used - proportion etc.
7. Quantity of fumigant required @ 1.5 to 2 lbs. per 1000 cu.ft.
8. a) Whether the main tubes and secondaries have been tested for easy flow of the fumigant.
b) No. of mains used with 'windows' and their length.
c) No. of secondaries with 'windows' and their length
d) No. of 'T's and 'Y's used
e) Whether the mains and secondaries have been properly fixed and placed in position?
f) Whether the ends of the secondaries have been placed on the 'fumigant vaporiser'?
g) Whether arrangements have been made for protecting the mains and bottom sealing from rats?
9. Whether the required No. of samples of all types and grades of commodities were drawn and properly labelled?
10. Whether the insect exposure tubes with the insects have been inserted into the bags and placed in the stack in convenient bags; the No. of tubes so inserted and location marked.

11. a) Whether the cover(s) were spread in the open and tested for punctures/leakages/defects and repaired/mended?
b) Area of the cover(s) taken and whether they are sufficient to cover the stack completely and leave a margin of 2-3 ft. around.
12. a) Whether the cover has been properly spread leaving the above margin?
b) If more than one cover used whether the joints were properly rolled over to get leak proof seal and pasted as per prescribed instructions?
c) Whether the sand snakes were placed around on the margin of the cover taking care to see that the main tube housing was not pressed. Tied rope around the stack over the tent (fumigation cover).
d) Whether the two corners of the cover were tied with ropes and the ropes taken over to the ceiling/ventilator or pulley to facilitate easy lifting of the cover?
e) Whether the edges of the cover were sealed with sand/mud?
13. Whether it was ensured that no person other than the fumigation personnel were present on the spot?
14. Whether the gas mask with canister tested has been commissioned for use and work properly?
15. a) Whether the bolt has been removed and the nozzle fixed and tightened with the hose clamp; and placing the screw type pinch cock in position?
b) Whether the valve of the cylinder has been tested with the spindle key for easy operation with the bolt in position?
c) Initial roading of the balance with the spindle key.
d) Pinch cock examined and kept open.
e) Time at which the fumigant was released.
f) Whether it was tested and ascertained that there were no leakage of the fumigant.
g) Final readings of the balance.
h) Quantity of fumigant used.
i) Period for which the fumigant was discharged.
j) Whether the valve of the cylinder has been closed tightly with the spindle key?
k) Whether the pinch cock was tightened and the main tube attached to the hand compressor and air blown after loosening the pinch cock for flushing the fumigant in the tubing system?
l) Whether the pinch cock was again tightened and the opening of the main tube fixed with a solid metal (or glass) rod?
m) Whether the nozzle was replaced by screwing the bolt tight and the hood closed?
n) Whether the main tube has been secured and placed in a safe position?
o) Whether the quantity of the fumigant used was noted on the cylinder card?
p) Whether the period for which the canister was used was noted on the canister card with remark on the exposure to fumigant, if any.
q) Whether leak detector was used, colour of the flame noted.

- 5-
18. Whether a warning signal noting thereon the date and time of fumigation has been put up conspicuously on the door.
 19. Whether proper instructions were issued to the watchman of the godown?
 20. Whether periodical inspections were conducted to ensure that the arrangement was not disturbed?

AERATION OF THE STACK UNDER COVER FUMIGATION

1. No. and address of the godown fumigated
2. Date and time of fumigation.
3. Time and date on which aeration was taken up.
4. If an interval of less than 45 hours was allowed, the period so allowed and the reasons thereof.
5. Whether it was ensured that no person other than the aeration personnel with the gas mask on, was present in the vicinity of the godown?
6. Whether it was tested with the leak detector wearing gas mask on that there were no leakages of the fumigant and that the arrangement was not disturbed?
7. Whether the front portion of the cover was taken up with the ropes and the concentration was observed at different intervals?
8. Period for which high concentration was observed.
9. When the concentration fell below safe limit whether the cover was completely removed and spread out with the inner surface exposed in the open for aeration?
10. Whether an entry was then made with gas mask on into the godown and the paper strips, etc., torn out to facilitate greater aeration.
11. Time at which the aeration was complete and no trace of the fumigant found inside or outside the godown.
12. Whether insect exposure tubes were collected and mortality observed. Counted to recover all the exposure tubes placed in the stack?
13. Whether all the tubings, etc., were removed and exposed in the open for aeration. Flushing with compressed air carried out?
14. Whether sufficient number of samples (at least 4 nos.) were drawn and one sample each sent to CFTRI for residue analysis, etc., with the detail particulars of treatment?

Particulars: a) Sample drawn before fumigation:

b) Sample drawn after fumigation:

15. Whether all the tubings, covers, etc., were removed and laid in the open for aeration before packing and carrying those?
16. Whether instructions were issued to the watchman of the godown not to allow any person inside the godown for one hour after opening the godown every day, for a week?
17. Whether the warning signal was taken off and a clearance certificate issued?
18. Whether the period for which the canister was used was noted on the canister card and the mask placed in suitable container separately and stored away from fumigant containers, covers and tubings?

DUROBASE SPRAY TREATMENT OF PROPHYLACTIC GUNNY CLOTH

1. Dimensions of the stack: Length Ft.
Breadth Ft.
Height Ft.
2. Type of stacking A-Twill
B-Twill
Heavy cees
D.W.flour bag fabric
3. Size of gunny cloth Length Ft.
Breadth Ft.
4. Particulars of sprayer and nozzles used:
 - a) Make and type
 - b) Tank capacity
 - c) Lance and hose length and type
 - d) Nozzle type Swirl
Fan
Low Vol.
High Vol.
5. Orifice: mm.
6. Durobase:
 - I Batch
 - II Batch
 - III Batch

Volume taken in sprayer ml.

Volume actually sprayed on each gunny cloth Ml.
7. Test fabric 6" x 6" piece sample: Identification mark and number.
(to be sent to the CFTRI along with the samples of grain, etc., drawn before and after fumigation).
8. Covering of the stack with durobase treated prophylactic cloth done before or after fumigation.
9. Prophylactic Durobase spray on walls, doors and windows of the warehouse around the treated stack.

Area sprayed
Nos. of Doors.
No. of windows/ventilators
Quantity of Durobase I, II and III
used during last one year (Dates):
10. Inspection of the treated wall, and stack:

Living insect present or absent:
Remarks on the general conditions
of the treated warehouse:
11. Any special observation or Remark.

VII. A SCHEDULE FOR INFESTATION CONTROL IN STORED FOODGRAINS.

Cereal grains, pulses, spices, oilseeds, oil seeds cakes, etc., are attacked by various insect pests during storage. Insect infestation may occur in the commodities under warehouse conditions or before harvest in field conditions. Under tropical conditions of temperature, the insects multiply at a rapid rate on the materials and deteriorate a considerable portion within 3 to 4 months' storage period.

The control of insect infestation in the grains can be carried out by a two pronged approach i.e., (1) killing of the existing infestation, (2) preventing further infestation from outside sources. The former is achieved by the use of volatile or gaseous chemicals and the latter is carried out by the application of essentially non-volatile and residual pesticidal chemicals.

Although the control of insects is carried out by toxic chemicals, these should not leave any harmful residues on treated food materials. Proper application of the chemicals with intelligent understanding with regard to their properties can give successful control of insect infestation without endangering the health of the consumer.

Usually the programme with regard to the control of pests, for stored foodgrains should start even with the construction of the warehouses. A phased programme for storage and infestation control treatment of the grains is given below:

Phased Programme for Treatment of Grains in Storage:

(i) Structure of the Warehouses; Follow the specifications of the Indian Standard Institution, for the godown structures as specified on regional basis. Special emphasis should be laid on the design of the structures, with reference to rodentproofing and harbourage of the insect pests on the walls, corners, etc.

(ii) Treatment of the empty godowns: (a) Annually, the godowns should receive spray of residual insecticides in a water dispersible composition, on the walls, roofs, doors, ventilators and also other materials like the dunnage structures. DDT/Lindane formulations for giving a deposit of 50-100 mg./sq.ft. should be sprayed in adequate quantities with either low volume nozzle knapsack type sprayer, or a power sprayer with low volume nozzle attachment. After spraying, the doors and windows and the ventilators of the warehouse should be kept open for a few days to get rid of the excess moisture on the walls.

(b) The Dunnage materials, empty gunny bags, handling and sieving equipment and other implements should be fumigated either under a gas proof sheet or in a small air-tight room with $1\frac{1}{2}$ -2 lbs. of MB/1000 cft. dosage with an exposure period of 36-48 hours. or 0.5-0.75lbs/1000 cft. of EDB:MB (1:1) mixture.

(c) Spilled grains, frass, and other sweepings should be collected and burnt. These may also be used for preparing poison baits for rats.

(iii) Treatment of the commodities: (1) The moisture content of the grain should be assessed either with the moisture meters or by experience. If the moisture content of the grain is above 11%, the grain stock should be exposed in thin layers for drying either in a shed or in the sun. The moisture content, should preferably be brought down to a level below 11%.

(2) If the grain is exposed to the sun, before packing it is to be cooled by spreading in thin layers. Keeping this in bulk should be avoided until it attains the room temperature.

(3) Disinfested bags should be used for filling the grains. The dunnage material should be sprayed and care should be taken that these materials are sufficiently dried. Polyethylene sheet (300-400 gauge) can be used as a dunnage material.

(4) The dunnage frames made up of wood or other materials could also be used which should have a minimum clearance of 4" from the floor level.

(5) The floor and adjacent area of the building should be cleaned thoroughly of all chaff or frass materials and also the husks. The dunnage racks or materials, should be treated with a non-volatile oil based composition of DDT or Lindane.

(6) Stacks should be neatly built on the dunnage material, keeping at least a clearance of $1\frac{1}{2}$ ' from the wall. The arrangement of bags should be with a view to occupy minimum space. During stacking, care should be taken so that the bags do not get displaced and fall during manipulations. The bonding of bags like the brick bonding (criss-cross) should be adopted for stable stacking and packing maximum number of bags within the least volume.

a) Prophylactic Measures:

(1) If the bags are of very close weave and good textured, dust formulations containing pyrethrin 0.2% and piperonyl butoxide 2% can be used at the rate of 8 oz./100 sq.ft. on the surface of the stack. It should be repeated every 2-3 weeks. Mineral oil like Kerosene, white oil or water dispersible formulations should not be applied on grain bag stack.

(2) A high viscosity non-volatile oil based formulation of Lindane can be sprayed on the peripheral or external aspect of the bag stack. In case of bags with loose textures having a high weave clearance, old gunny bags opened and stitched together in the form of a sheet can be spread over the bag stack as a prophylactic cloth and treated with high viscosity oil based insecticidal formulation. A dosage of 50-100 mg./sq.ft. of the insecticide of DDT-Lindane will be required for an effect lasting 8-10 months.

(3) A process, for making ordinary empty gunny bags insectproof, has been developed at the C.F.T.R.I., Mysore. In the grain bagging centres, the machines can be installed by cooperative or marketing

societies. These insectproofed gunny bags can be used for filling the freshly harvested grains. Paddy, pulses, cereals, arecanut, turmeric, dried tapioca chips, cumin, coriander, if these freshly harvested, dried and threshed, can be stored in the insect-proofed gunny bags for 6-8 months without any other treatment.

b) Curative measures:

(1) Fumigation with EDCT (Ethylene dichloride and carbon tetrachloride) mixture under gas-proof sheet (standard fumigation cover) at every 3 months interval, should be carried out with 30-35 lbs./1000 cu.ft. dosage and an exposure period of 48 hours. ONLY CEREALS AND PULSES CAN BE TREATED BY THE FUMIGANT MIXTURE. Oilseeds, oil-cakes, milled grains, tobacco, tamarind, dried fruits, coffee beans, turmeric, arecanut, etc. cannot be treated with EDCT mixtures.

(2) Fumigant mixture, containing EDB and MB can be used on cereals, pulses, oil-seeds, oil cakes, crushed and milled grains, coffee beans, tobacco, arecanut, turmeric and other materials. Under gas-proof sheet, the fumigation can be carried out at a dosage of 1-3 lbs./1000 cu.ft. depending on the type of commodity.

(3) Schedule for fumigation is given in Table below:

Commodity	Fumigant and dosage (Lbs/1000 cu.ft.)				Prophylactic treatment on stacks		
	EDCT*	MB	+	EDB**	Lindane dust (every 3 weeks)	Pyreth- rin dust (every 2 weeks)	Lindane in Duro- base (every 6 months)
1	2	3	4	5	6	7	8
Paddy	25	1.0	0.75	2.5	+	+	+
Rice (Polished)	30	1.5	1.50	4.0	-	+	+
Rice (Unpolished)	35	2.0	2.00	4.0	-	+	+
Wheat	35	2.0	1.50	4.0	-	+	+
Sorghum	35	2.0	1.50	4.0	-	-	+
Barley	35	2.0	1.50	NS	+	+	+
Maize	35	2.0	1.00	3.5	-	+	+
Groundnut	NS	2.0	1.75	NS	-	+	+
Sesame	NS	2.0	1.75	NS	-	-	+
Cottonseed	NS	2.5	1.75	NS	+	+	+
Copra	NS	2.0	1.50	NS	-	+	+
Pulses	30	1.5	1.00	4.0	-	-	+
Cumin	NS	2.5	1.75	NS	-	+	+
Coriander	NS	2.0	1.50	NS	-	+	+
Turmeric	NS	1.0	0.75	NS	-	+	+

Table (Contd.)

1	2	3	4	5	6	7	8
Chilli	NS	1.5	0.75	NS	+	+	+
Areca nut	NS	1.5	0.75	NS	-	+	+
Coffee beans	NS	2.5	1.50	NS	-	-	+
Tapioca chips	NS	2.0	1.00	3.5	-	-	+
Tamarind	NS	2.0	1.00	NS	-	-	+
Tobacco leaves	NS	2.5	1.50	NS	-	+	+
Oilseed cakes	NS	3.0	2.25	NS	-	-	++
Atta	NS	3.0	2.50	NS	-	-	++
Flour (maida)	NS	3.0	2.20	NS	-	-	++
Bengal gram flour	NS	3.0	2.00	NS	-	-	++

* Refumigation every 3-4 months will be required

** Can be applied only in small stacks

+ Safe to use for prophylactic treatment

++ Should be applied on prophylactic gunny cover.

NS Not suitable for fumigation of the commodity; cannot be applied without the risk of contamination.

"DUROBASE" -(An oilbase composition developed by CFTRI, Mysore.)

Dosage of the fumigant can be reduced if the temperature during fumigation is higher than 27°C. The proportion of EDB should increase with the increase in temperature and proportion of MB should increase with the decrease in temperature.

IV. Inspection of the stacks:

(i) Periodic sampling of grains from the peripheral bags and also some of the internal bags, should be carried out after an interval of 15 days. The samples can be examined for (a) Kernel damage, (b) insect count, (c) viability, (d) texture, colour and taste and also moisture content. Moisture content in the lower bags should not exceed 12% in the case of cereals and pulses. The weight of some marked bags in the stack can also be recorded from time to time.

(ii) Collect spilled grain; look for damaged and chewed kernels. Collect flour and broken grain particles. Examine signs of insect infestation by the presence of cast skins, webbing. Look for resting and crawling insects at the seams of the bags, edges of the stack, junction of wall and floor and top surface of the bag stack. Examine cracks and crevices for hidden insects. Examine thoroughly the bag and dunnage intersurfaces.

The above inspection should be carried out every 15 days.

Rodent Control measures:

(i) Fumigation of rat burrows on roof, wall and around the building and closing of access to the rats from outside sources and yearly

godown fumigation with low dosages of EDCT or EDB and MB will be adequate for rodent control. Poison baiting within the godown premises, should be avoided. A few permanent baiting stations can be kept in warehouses, where infestation by rats is quite heavy.

(ii) Several rodent poisons are available in the market. Anti-coagulants such as warfarin or tomorin are safer than the other poisons like AMU, Zinc phosphide, 1080, etc. Although moist baits are more acceptable than dry baits, the moist baits spoil very rapidly.

(iii) Disposal of dead rats and left over poison baits should be carried out with care, so that dogs, cats, other domestic animals and children do not get access to these materials.

(iv) Placing the baits should be carried out with proper study about the run and entrance and exit points of the rodents.

(v) Usually good house-keeping, sanitation and elimination of harbourages in and around the building will minimise rodent infestations.

(vi) Use dunnage racks and keep space around the stack. Close all accesses with mesh. Destroy all litter, empty cans, floor sweepings.

(vii) In case of new building, the rat-proofing measures should be incorporated in the constructional features of the building.

Control of birds: Birds also contaminate grain with their droppings in addition to the spillage and eating substantial quantities.

Screening of the ventilators, windows and other accesses with wire mesh, repair of roof and walls and blocking all points of entry are the preventing treatments.

Fumigation with sulphur dioxide and use of bird repellent (proprietary products) can be carried out as curative measures.

Control of Mites:

The mite infestation will not ordinarily occur, if the moisture content is kept within the safe limit and the usual curative and prophylactic measures necessary for the control of insect infestation are adopted. Infestation by mites, will indicate that insect control measures taken were not satisfactory and also the moisture content of the material was kept higher than the safe level. Fumigation with EDB-MB mixture should be adopted for the control of mites. Ethylene oxide in admixture with carbon dioxide can be used for the control of mites, but, it is not practicable to apply it under warehouse conditions. Atmospheric vaults or vacuum fumigation chambers are required for fumigation with ethylene oxide.

V. C A U T I O N:

(a) In the general godown sanitation programme, insecticidal

dusts containing BHC, DDT, Lindane or any other residual insecticide, should be avoided, as the particles get transported and give rise to food contamination hazards. Mixing of insecticidal chemicals with foodgrains should not be carried out.

(b) All chemicals used for insect control are also poisonous to human beings and pests, contamination of the pesticidal chemicals to grains should be avoided scrupulously. Sometimes the carriers or solvents used for spraying pyrethrin, malathion and other pesticides are more hazardous than the insecticides themselves. Use of these carriers should be avoided so that grains are not contaminated with them.

(c) All fumigation work should be carried out by trained persons with adequate protective kits. Training facilities for Pest Control Operators on the special fumigation and other processes are available at the Central Food Technological Research Institute, Mysore.

(d) Residual insecticides such as DDT, BHC, Aldrin, Dieldrin, Endrin, Chlorodane, Toxaphene, etc., when present in foodstuffs in low concentrations are also harmful to human health as they offer possibilities for chronic toxicity. It is therefore that indirect contamination to the foodgrain should be within permissible limits. The Food, Drug and Health departments prescribe safe limits of pesticides in foodstuffs in various countries. These should be strictly adhered to during the adoption of pest control programmes in foodgrain storages.

Some selected readings:

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3. CFTRI, Mysore, Project circular No.3(Revised). The Durofume Process for Infestation Control in Foodstuffs. 1958.
4. I.S.I.Standards: IS:604, IS:605, IS:606, IS:607, IS:608.
5. Insectproofing of gunny bags for grain storage: Res. & Ind., 1961, 6, 391-393.
6. Coyne, F.P. Principles of Cereals Storage, Govt. of India, Department of Food Publication 1943.
7. A.A.C.C. Monograph, Vol.II - Storage of cereal grains and their products, 1954. Am.Assoc.Cer.Chem., Minnesota.

VIII. FIRST AID PRECAUTIONS.

ACCIDENTS ARE CAUSED AND THEY DO NOT HAPPEN. It is to be remembered that an efficient fumigant requires less quantity to be handled while a weak and inefficient fumigant will require large quantities to be applied, handled and degassed, the associated problems should be viewed with due respect to the properties. So called safe chemical causes more accidents and damages to health due to the negligence in handling and disregard of its true toxicological properties. All fumigants being basically toxic to insects and also to man the protective gas masks and kits are essential when used for largescale fumigations for protection from health hazards. Degassing of an inefficient fumigant is more difficult and time consuming because of the quantity of the same to be applied for fumigation as compared to a low dosage fumigant.

In case of pesticide poisoning CALL A PHYSICIAN IMMEDIATELY.
Awaiting Physician's arrival, apply FIRST AID.

1. Swallowed poisons: Remove poison from patient's stomach immediately by inducing vomiting. Give common salt $\frac{1}{2}$ oz. in a glass of warm water and repeat until vomit fluid is clear. Gentle stroking or the touch of the throat with the finger or by placing the blunt end of a spoon will aid in inducing vomiting when the stomach is full of fluid.

IF THE PATIENT IS ALREADY VOMITING, DO NOT GIVE EMETIC OR VOMITING SUBSTANCE BUT GIVE LARGE AMOUNTS OF WARM WATER THEN FOLLOW SPECIFIC DIRECTIONS SUGGESTED.

Do not induce vomiting if the patient is in coma, unconscious in convulsion and when the patient has swallowed petroleum products, kerosene, gasoline, etc., and corrosive acids or caustic alkalies (symptoms: severe pain, burning sensation in mouth and throat and vomiting).

2. Inhaled poison:

- a) Carry patient (Don't let him walk) to fresh air immediately.
- b) Open all doors and windows
- c) Loosen all tight clothing.
- d) Apply artificial respiration if breathing is stopped or is irregular. Avoid vigorous application of pressure to the chest.
- e) Prevent chilling.
- f) Wrap patient in a blanket.
- g) Keep patient as quiet as possible.
- h) If patient is convulsing, keep him in bed in some dark room. Avoid jarring noise.
- i) Do not give alcohol in any form.

3. Skin contamination:

- a) Drench skin with water (shower, hose or pump).

- b) Apply stream of water on skin while removing clothing.
- c) Cleanse skin thoroughly with water.
- d) Do not use chemicals. They may increase the extent of injury.

4. Eye contamination:

- a) Hold eye lids open.
- b) Wash eyes with gentle stream of running water immediately.
Delay of even seconds greatly increase the extent of injury.
- c) Continue washing until physician arrives.
- d) Do not use chemicals. They may increase the extent of injury.

5. Prevention of collapse:

- a) Cover the patient with a light blanket.
- b) Do not use a hot water bottle.
- c) Raise feet on bed.
- d) Apply elastic bands on arms and legs.
- e) Give strong tea or coffee. Tea is useful for children.
- f) Hypodermic injection of stimulants, such as, caffeine and epinephrine.
- g) Fluid administration of dextrose 5% intravenously.
- h) Blood Plasma transfusion.
- i) Do not exhaust patient by too much or too vigorous treatment.

IX. ANTIDOTES

Administer antidotes immediately and properly.

A. General antidotes:

1. Removal of poison: Remove poison by inducing vomiting.
2. The 'Universal antidote': Half an ounce of activated charcoal two parts, Magnesium oxide one part, Tannic acid one part in half a glass of warm water may be used to absorb or neutralise poison. This mixture is useful in poisoning by acids, liquid glycosides and heavy metals. Give it after gastric lavage or an emetic (substances inducing vomiting), except in cases of poisoning by corrosive substances.
3. Gastric lavage: (Removal of stomach contents) Lavage is the most important method in removing poison from stomach. Ordinarily gastric lavage is not indicated unless the patient is seen within the first four hours after the poison has been swallowed. Serious injury may result from the improper use of the stomach tube and this procedure should be carried out by a physician.

The 'Universal Antidote' or a specific antidote should^{be} administered orally with water before the tube is passed.

The stomach tube should not be used after poisoning by corrosive acids or caustic alkalis.

4. Demulcents: (Substances having soothing effect): After the stomach has been emptied as completely as possible, give one of the following:

Raw egg white mixed with water, gelatine $\frac{1}{2}$ to $\frac{2}{3}$ oz. dissolved in $\frac{1}{8}$ gallon of warm water, butter cream, milk, mashed potato or flour and water.

B. Specific Antidotes for some Pesticides:

The following emergency treatments are preferable for the treatment of some specific pesticides, while awaiting the physician:-

1. BHC, DDT, etc.: If swallowed give "Universal Antidote" followed by gastric lavage. Then give one ounce of magnesium sulphate in a glass of water followed by hot tea or coffee. Inject 10 cc. of 10% calcium gluconate intravenously. If necessary, inject phenobarbital 0.1 gm. intravenously. Feed the patient with rich carbohydrate and calcium diet to prevent liver damage.

2. Methyl bromide and Ethylene dibromide: Remove the patient to fresh air immediately and keep him warm. Administer oxygen therapy. Inject caffeine sodium benzoate 0.5 gm. If necessary, inject epinephrine 0.5 cc. 1:1000 subcutaneously. Keep the mouth rinsed always with 10% solution of sodium thiosulphate. When revived, give hot tea or coffee.

The following measures are suggested for use by the physician in accordance with his own judgement. Nausea accompanied by vomiting is treated by administering intra-venously Ringer's solution (Isotonic Saline) together with a circulatory stimulant. If vomiting is not satisfactorily controlled in this way, Dramamine, or a similar drug to counteract vomiting should be tried. If there is evidence of cardiac or circulatory failure, intravenous or subcutaneous administration of coramine, or subcutaneous administration of caffeine sodiobenzoate is recommended.

In subacute cases resulting from more prolonged exposure to moderate concentrations, headache, dizziness and double vision may provide warning symptoms. These may persist or reappear with periods of remission over several weeks. If any such symptoms are noticed, the patient should see a doctor immediately.

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE, MYSORE

INDUCING LONGER STORAGE OF FOODGRAINS
BY USING INSECT-PROOFED GUNNY BAGS

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of The problem of conservation of the foodgrains will assume proportionate magnitude with the level of production. The present production figure is 88 million tons. It is anticipated that, by 1966-67, the total foodgrain production will be about 110 million tons. Therefore, the problems of storage, movement and utilization of the foodgrains will be of equal magnitude. Considerable attention is, no doubt being paid to the imported grains for proper storage. But, the producers' stocks, which constitute grains nearly 75 per cent of the total foodgrain production, have not yet received adequate attention for proper storage. The Agricultural Produce Corporation Act (1956) envisages to plan and promote programmes for the production, processing, marketing, storage, warehousing, export and import of agricultural produce through the Warehousing Corporation and Co-operative Societies. The indigenous produce will also be required to be stored with the same technical attention as that given to the imported grains and the buffer stocks maintained (4-5 million tons) by the Central Food and Agricultural Department.

Fumigation kills the existing infestation. But during transit and storage in godown, the insect pests migrate to the fumigated stocks and re-infest within a short time. Almost all godowns harbour different stages migrate to the grain stacks. Cross infestation of a fumigated stack from an infested neighbouring stack is not uncommon. This makes the adoption of frequent fumigation treatments and BHC dusting of the surfaces of the stacks at frequent intervals imperative. The cost becomes tremendously high for one year of insect-free storage.

The processes developed at the Central Food Technological Research Institute, Mysore, on the Insect-proofing of jute bags deserve wide application as a preventive measure for the control of insect infestation of foodgrains.

The process consists of impregnating the jute bags with insecticidal chemicals on the outer aspect only, which prevents the entry of insects into the bags from outside sources. The process have been developed for treating individual bags and also for insect proofing of a stack in situ. It is estimated that about 150 to 200 million jute bags are in continuous use in India, in which the grains are filled.

The greatest hazard to the grains stored in bags is the insect pest. The bags, as they carry 15 to 20 million tons of foodgrain in Indian urban and village storages, form the major receptacles.

The grains after harvest, especially the marketable surplus, which amounts to slightly less than 25 per cent of the total food production, form the commercial supply. These are brought to the Regulated Markets, Mandis and local markets for auction or sale. The usual transport of grains at this stage is in bulk, not in bags. After the auction or the sale, the wholesale merchants bag the grain in different types of gunny

bags. It has been estimated that 16.7 million tons in 1956-57 and 15.3 million tons in 1957-58 were the marketable surpluses of cereals. With increased production an increasing volume of grains will flow through these markets. The Indian Standards Institution, Directorate of Marketing, Government of India, and the Ford Foundation Team have laid emphasis on the development of Regulated Markets to promote orderly marketing, adoption of fair trading practices and competitive conditions in buying and selling. This point of the grain flow, offers unique opportunities for giving disinfection treatments.

For augmenting the national food resources, the saving of the foodgrains from the depredations of insect pests will no doubt be a positive step in the direction. The foodgrains produced in the country require organised and practical insect control treatments on a nation-wide scale, similar to the attention and treatment given to the imported foodgrain stocks. To achieve this objective, the first step should be, to establish or licence small-scale organisations in the grain bagging centres for supplying insect-proofed gunny bags to the grain merchants. The grains after harvest are brought to the towns by the cultivators to the municipal or regulated markets for sale or auction. The wholesale merchants buy the grains in bulk and bag them for distribution.

In the regulated market yard, small units for treating the bags with the pest-proof emulsion (active ingredients Lindane, DDT) by the Pest-Proofing machine developed at the Central Food Technological Research Institute, Mysore, of the Council of Scientific & Industrial Research, may be established. Depending on the size of the treatment, the Pest-proofing machine, both power and hand-operated may be installed for the purpose. The same machine can be introduced for insect-proofing of jute bags after the bags are manufactured and sent for grain bagging. However, for an effective result, the bags should be used within 1-2 weeks after giving the pest-proofing of jute bags after the bags are manufactured and sent for grain bagging. However, for an effective result, the bags should be used within 1-2 weeks after giving the pest-proofing treatment.

As by these small firms, the insect-proofed gunny bags will be made available to the wholesale merchants at the bagging centre, reinfestation of the bagged grains will be minimised at least for a period of eight to ten months. Any conservative estimate of the reduction of losses through this treatment alone of the newly harvested grain before storage in godowns, will be in the neighbourhood of at least 75%.

At the insistence of the Central and State Governments, the grains filled in insect-proofed bags in the regulated market, yards may also be fumigated with the DUROFUME fumigant mixture by which treatments, all losses of stored grains through insect attack can be prevented. After these treatments, the bagged grains will be in a suitable condition to be transported and distributed without any danger of being infested for a period of eight to ten months.

As stated earlier only 25 per cent of the total harvest can form the commercial supply, while 75 per cent of the total production

of foodgrains are stored in rural storages. The problem of insect infestation and mould growth in the rural stocks is quite serious and also requires attention of the scientific workers. Paddy, pulses, sorghum and other grains are infested even during the pre-harvest period. Pests like, Sitophilus oryza, Sitotroga cerealella and Bruchus chinensis infect grains in their preharvest conditions and cause serious depredations during the subsequent storage period. This aspect has generally been overlooked. It is, therefore, desirable to disinfest grains either before harvest or immediately after harvest so as to keep the wastage to the minimum. Since the application of measures like fumigation with noxious gases cannot be applied by the untrained farmers, attempt has been made to replace the fumigation treatment by a comparatively simpler method of spraying the ripe grain at the preharvest conditions to eliminate the initial field infestations. It is, therefore, desirable to disinfest grains either before harvest or immediately after harvest. Parkin in a review stated that the application of measures like the fumigation with noxious gases, unfortunately lags sadly behind the advance of knowledge. An attempt has, therefore, been made to replace the fumigation treatment by a comparatively simpler method of spraying the ripe grain at the pre-harvest condition to eliminate the field infestations. Insect-free storage has also been attempted by storing the grains in insect-proof containers and preventing cross-infestation by prophylactic treatments. Very few insecticides are highly effective within their prescribed tolerance limits on foodgrains as fixed by different countries. Rapid decay under field conditions and handling is also one of the considerations for the selection of a pesticide for the pre-harvest prophylactic spraying on the panicles of cereal crops. Malathion seems best suited for the purpose on account of its high arthropod toxicity and low mammalian toxicity, ease in the formulation of water dispersible composition and the required degree of persistence and biological efficacy. Data on the efficacy of the field prophylactic treatment on sorghum and its storage in insect-proof bags are presented in Table I. The results of the study indicated that this simple treatment could replace the highly technical process of fumigation for disinfestation of foodgrains. (Table I). Insect-proofing of the structures, containers and gunny bags can be introduced successfully for the insect-free storage of the freshly harvested grains disinfested by the preharvest prophylactic treatment. Experiments carried out at this Institute have shown that malathion is the best suited for the purpose of preharvest prophylactic spray treatment of the panicles of foodgrain crops due to its low toxicity to man, high toxicity to insects at low concentration even below its permissible limit in foods. This simple approach is having the possibility of replacing highly technical process of fumigation for disinfestation of foodgrains in the rural areas.

This approach for organising nation-wide disinfestation of grains will be a practical, efficient and the cheapest in consideration of the results that can be expected. It is imperative that the most efficient process will be in this direction, i.e., only by treating the grains at its origin, from which place the grain bags are further distributed.

Preharvest Disinfestation:

Field infestation of Sitophilus Oryzae on crops like wheat, jowar, Maize can be controlled by the use of insecticides, right at the time of their oviposition and larval stage. Also other pests like Stenocroid (the webbing caterpillar) in the case of jowar, Bruchus chinensis in the case of pulses can be controlled in cereals and pulses.

This field infestation is responsible for post-harvest damage to seeds even though the seeds are treated with seed dressing materials.

Malathion has to be used as preharvest spraying emulsion at the rate of 20 gallons per acre (Spray volume). The total deposit of the insecticide per acre will be 500 g. at this rate, with a 0.5% emulsion. The quantity of the insecticide deposited can be varied from crop to crop, depending upon the season of harvest and frequency of infestation.

In the case of jowar, two sprays have to be given, one at the milky stage (when pests other than stored grain pests also attack the crop) and one on the day of harvesting the crop. Such a treatment will take care of infestation and spoilage due to more than one kind of pests, hence resulting in a slight increase in the yield per acre.

In the case of pulses, malathion spraying has to be done at the time of pod formation. Periodical spraying over a period of a month or so, will keep the crop free from field infestation. In the case of pulses, spraying should be directed on to the crops, taking care to see that the insecticide will not be wasted on the foliage which cover a larger surface. In these cases malathion deposit can be reduced to 300 g. per acre.

The crop after harvest has to be then stored in pest proof structures (bag stack or any permanent structures), which is the second important stage of the treatment. This takes care of any fresh cross infestation, over a period of three months of storage.

The corn paddy, sorghum, pulses and many other crops are infested by stored grain pests just when the developing grains pass through the milky stage and in subsequent period. Disinfestation under field condition and subsequent protection for 2-3 months from cross infestation can be afforded by spraying with malathion to give an initial deposit of 10-20 ppm. on the inflorescence.

Spraying of water-dispersible formulation with power sprayers can easily be arranged through the contract servicing firms dealing with agricultural pest control. Typical results of spraying with low volume nozzle attachment in knapsack type of sprayer is given below for making suitable selection of concentration of malathion and spray volume. Ground spraying is more economical than aerial spraying for preharvest spraying for insect in corn cobs and other food crops.

Preharvest spraying of malathion

Spray volume per 10,000 sq.ft. (100' x 100')	Malathion concentration % in spray	Malathion in ppm
24 litre	0.3	9.4
23 "	0.6	20.1
21 "	0.9	38.2
40 "	0.25	7.3
40 "	0.5	16.3
40 "	1.0	40.2
40 "	1.5	73.7
40 "	2.0	138.4
40 "	2.5	194.3
40 "	0.3	14.7
60 "	0.3	28.8
80 "	0.3	27.1

TABLE -I

Effect of pre-harvest malathion spray and storage in insect proof bags on sorghum

Treatment	After 5 months of storage					
	Malathion concentration at the time of storage	Frass per cent	Kernel damage per cent	Uric acid/100 g.	Microbial countX 10 ³ /g.	Living adult count per lb.
Control in unimpregnated bag	0	4.0	24.6	19.6	140	1,565
Control in impregnated bag	0	2.8	20	15.9	174	1,280
Malathion treated in control bag	4.5 8.2	2.6 0.0	18 1.0	13.7 4.2	101 7	951 37
Malathion treated in insect-proofed bag	4.5 8.2	0.1 0.0	0.0 0.0	3.7 2.6	3 1	4 3
Fumigated and treated bag	0	0.0	0.1	3.2	1	3

PEST-PROOFING PROCESS

An insecticidal emulsion based on Lindane (Gamma BHC) was developed for impregnating jute bags (B-twill type) by dipping in an emulsion bath and the physico-chemical aspects of the study was carried out by Majumder and Pingale (1954). Further, Pingale and Majumder (1955) standardized a formulation based on Lindane and Dieldrin water dispersible type for impregnating B-twill bags by dipping in the emulsion which gave better insecticidal effects. Majumder and Pingale (1955) observed that in dipping the bags one after the other in the emulsion bath the jute bags exhibited preferential absorption of insecticides from the bath and as a result of this phenomenon, the first few bags dipped removed the major proportion of the insecticide and the subsequent bags did not receive an adequate dosage. (Table II) Further, Majumder (1957) studied that different sacking fabrics required different quantities of water for dispersion of the insecticidal emulsion and standardized conditions for B-twill, A-twill, D.W., Hessian and other jute fabrics. However, the dipping process for impregnating jute bags was not found adoptable for large-scale insect-proofing of bags. (Table III). A B-twill bag absorbed 2 litres (4-lbs.) of water, which fact alone became a limiting factor for large-scale application apart from adverse changes in the emulsion bath resulting in a precipitation of insecticides in some cases. Drying of bags containing 4-lbs. of water became an extremely difficult job as heat treatment could not be given without affecting the insecticidal potency of the insecticides. Majumder and Krishna Rao (1958) standardized a formulation and

TABLE II

Effect of progressive dipping of jute fabric
in lindane emulsion

Chemo-assay			Bio-assay	
Serial order of test piece dipped in emulsion	Effect level of impregnation, lindane fabric mg./60 g.	Lindane mg./60 g. jute fabric 1 sq.ft.	Serial order of test piece dipped in emulsion	%mortality* of L.oryzae after 30 min.exposure (counts after 24 hr.)
1	50	72.03	3	100
10	50	63.78	5	100
16	50	58.80	6	100
17	50	57.60	-	-
20	50	54.90	-	-
25	50	51.04	-	-
31	50	45.60	38	81
40	50	42.01	37	84
46	50	37.87	38	83
50	50	34.80	-	-
56	50	33.60	64	69
62	50	31.82	65	72
70	50	29.10	66	70

*Corrected for control response.

TABLE III

Relation of different fabrics and their weave clearance
with the infiltration time and emulsion uptake from bath

Fabric	Emul- sion* uptake per sq. ft.(ml.)	Emulsion uptake per g.of fabric (ml.)	Total em- ulsion reqd.for standard bags(ml.)	Infiltra- tion time (min) T. castaneum	Infiltr- ation time (min) C.oryzae	Weave clearance (per cent)
A-twill	104	1.48	1,800	205	90	2-5
B-twill	82.8	1.51	1,500	180	45	5-8
Heavy oes	69.6	1.50	1,250	175	35	7-12
D.W.	68.2	1.48	1,250	160	30	15-24
Plain	63.4	1.52	1,150	80	15	20-26
Hessian	48.1	1.60	810	15	5	55-70

* Emulsion oil in water type; containing Lindane+DDT with
acetone, xylene, groundnut oil, Dutrex and lissapol.

designed a machine for insect-proofing of jute bags by spraying. Emulsion- The pest-proof emulsion is based on Lindane and DDT. The solvents, vegetable oil synergists, stabilizers and emulsifiers are all indigenously available.

The composition of the emulsion is given below:

Lindane in acetone (40 per cent), 1000 ml.; DDT in xylene (30 per cent), 1000 ml.; kerosene (refined), 450 ml.; Turkey Red oil 50, 200 ml.; Dutrex-3, 2000 ml.; groundnut oil, 750 ml.; and Teepol B-300, 400 ml.

Spraying: The emulsion concentrate is diluted four times with water and sprayed at a regulated rate on the empty gunny bags fed on a conveyor belt. The equipment consists of a canvas conveyor lined with polyethylene film mounted on wooden mangles, the spray assembly and emulsion conduction system.

The emulsion reservoir is filled with the diluted pest-proof emulsion and pumped into the spray tank using compressed air. The feeding line is closed and the pressure in the spray tank is brought to 30 lb./sq. in., with the compressor having a pressure-stat. The wheel valve is opened and the emulsion allowed to flow through the two low-volume nozzles at 600 ml. per minute. Gunny bags are fed continuously on the conveyor belt at the rate of 16 bags or 53 ft per minute. A marker is provided to draw an indicating line on the bag to mark the sprayed side. The bags treated on one side are fed to the machine again for spraying on the other side. With skilled operators 2500-3000 bags can be treated in eight working hours. Drying is rapid as the moisture increase in the bag immediately after spraying does not exceed 2-3 per cent. The cost of insect-proofing of gunny bags works out to Re. 0.09 per bag (Table I).

The process has also been applied for insect proofing of fabrics, kraft paper, packaging films, liners for packaged goods, canvas, tarpaulins, hessian, matting and wrapping materials for cloth, cotton, carpet and other bales.

TABLE 1- Insect-proofing of gunny bags Cost estimates

(Basis: 2500 bags per day of 8 working hours)

Investment	Rs.
Equipment	
Wooden mangles with canvas conveyor belt and motor	700.00
Compressor (small with a pressurestat)	1250.00
Spray assembly	310.00
Trolley	180.00
Miscellaneous	110.00
Installation	50.00
	<u>2600.00</u>

Investment	Rs.
	2600.00
Building (shed with king roof)	5000.00
Working capital	6500.00
	<u>14100.00</u>

Direct Costs (Per day)

Pest-proof emulsion, 8 gal.	
Rs. 25 per gal.	200.00
Electricity, 12 units @ Re. 0.08 per unit	0.96
Labour and supervision	12.50

Indirect Costs (Per day)

Depreciation on equipment @ 10%	0.95
Depreciation on building @ 5%	0.70
Interest on capital @ 6%	2.35
Insurance on equipment @ 1.5%	0.12
	<u>217.58</u>

Cost of insect-proofing one bag	0.087
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The pest-proofing machine, developed at the Central Food Technological Research Institute, Mysore, can treat 3,000 to 10,000 bags per day. Each B-twill bag required about 40-ml. (40 gms.) to 50-ml. (50 gms.) of water. The drying of treated bags did not become a serious problem. The contamination of the grains with the insecticides was less in this type of insect-proofing of jute bags than in the dipping process. In view of high mammalian toxicity of dieldrin, it has been eliminated and replaced with DDT, which is safer for mammals. Fundamental studies on the vegetable and mineral oil synergists have revealed that insecticidal potency of DDT could be enhanced many times and thus could be used successfully in the emulsion for insect-proofing of jute bags and other fabrics. The empty gunny bags are made insect-proof in the machine with the Pest-Proof Emulsion only by spraying the outer (external) side of the bags. After drying, the bags are recommended for filling with the foodgrains. Latest development in the field indicate that the dry process developed at this laboratory can also be adopted for insect-proofing of gunny bags. The treated bags will remain effective for 10 to 12 months after which retreatment is necessary.

The process has further been improved which are as follows:

This invention relates to a process for the treatment of gunny bags of cotton, jute and other fabrics used for storage of foodgrains and other commodities free from insect infestation.

A process for insect proofing of gunny bags has been described

by the inventors (Majumder, et al., Research & Industry, 1961, Vol.6, No.11, pp.391-393) for large-scale treatments of gunny bags with a formulation and the equipment 'Pest Proofing Machine'. The said formulation comprises "Lindane" in acetone, DDT in xylene, Kerosene (refined), "TRO-50", "Dutrex-3", groundnut oil "Teepol". However, the emulsion composition described hitherto for insect-proofing of gunny bags undergoes deterioration both with regard to its stability and insecticidal action during the storage of the composition due to the impurities present in the insecticides used. Separation of the emulsion in the spray tank is also observed which affects the efficacy of the insecticidal impregnation adversely. The rapid loss of insecticidal potency on treated gunny bags is also a serious problem.

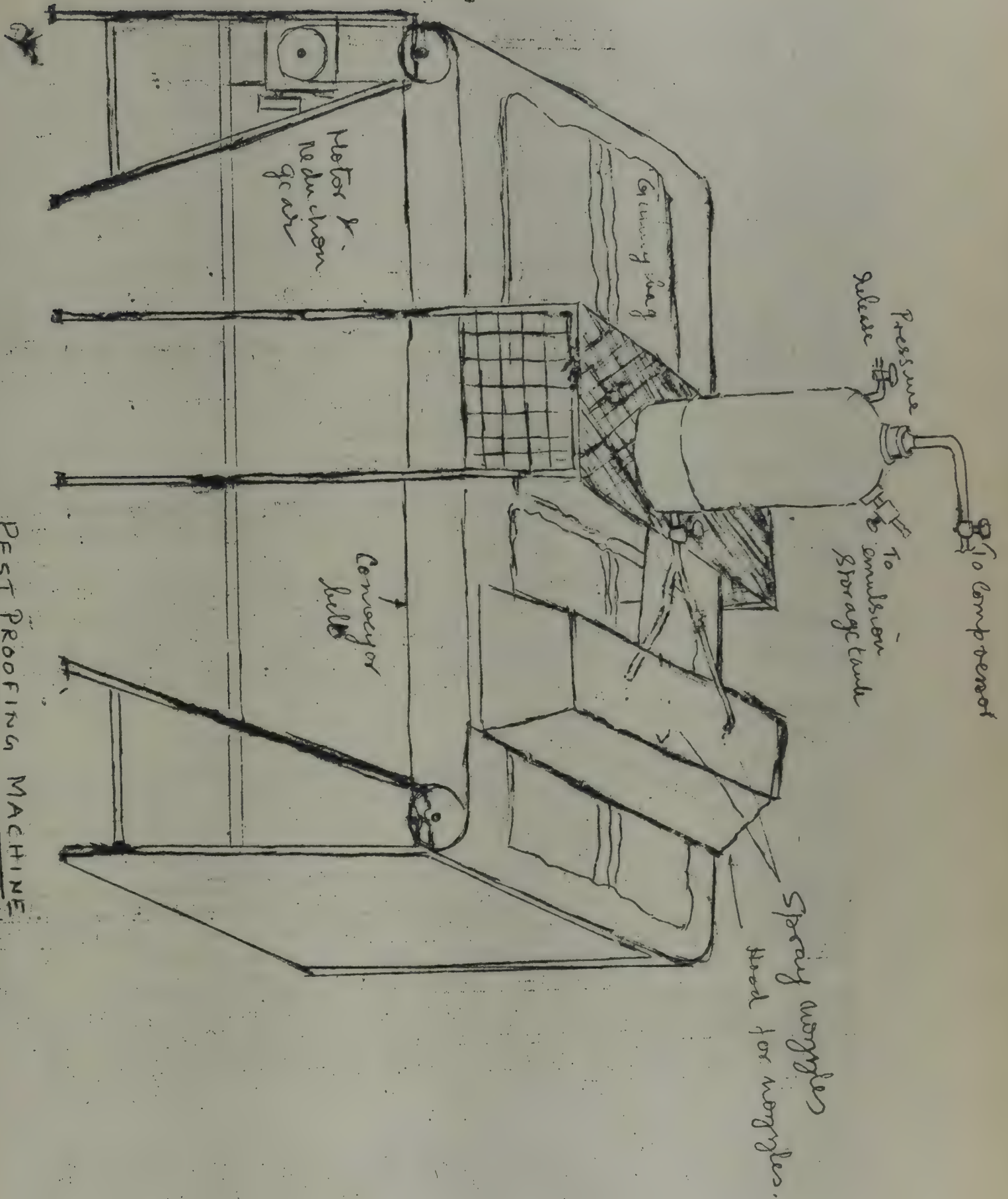
The defects referred to above have been overcome by modifying the formulation and technique of emulsification.

The invented process for the insect proofing of gunny bags consists in treating them with a water dispersible emulsion prepared by mixing (A) an insecticides fraction with (B) an oil emulsion is characterised in that the fraction (A) is obtained by mixing solvent (such as acetone, xylene or toluene) solutions of insecticides purified as indicated herein-below:-

<u>Insecticide</u>	<u>Purification is effected by differential solubilization in the following solvents:</u>
i) technical "BHC" (hexachlorocyclohexane)	methyl alcohol or warm kerosene (40-50°C)
ii) technical "DDT" (dichlorodiphenyltrichloroethane)	acetone
iii) technical "Malathion" (O,O,-dimethyl dithiophosphate of diethyl mercapto-succinate)	ethylene glycol followed by ethyl alcohol or xylene.

The active insecticidal ingredients of BHC, DDT and "Malathion" respectively are separated by cryometric crystallization, dissolved in solvents such as acetone, xylene or toluene, and the solutions are mixed to form fraction (A).

Fraction B is made by mixing high viscosity oils such as 'Jute batching oil', 'Dutrex-3' (petroleum compounds light bron oil, used as medium batching oil in textile industry and extenders for surface coating industry), groundnut oil, coconut oil and sesame oil with emulsifiers such as 'Lissapol' (octylcresol polyether alcohol), 'Lissapol'-paste' (octylcresol polyether alcohol paste), 'sulphate castor oil', 'Lubrol' (fatty alcohol ethylene oxide condensate), 'Triton' (alkylated aryl polyether alcohol), and 'Tweens' (polyoxyethylene sorbitan monooleate).



PEST-PROOFING MACHINE

The machine consists of the following components:

- i) Conveyor belt; ii) Spray assembly; ii) Emulsion conduction system.

Two types-of units have been designed:

- a) Hand-operated (@ Rs. 500/- per machine).
- b) Mechanically-operated (4 Rs. 2,500/-per unit).

No foreign exchange is involved in the manufacture of the PEST-PROOFING MACHINES. The compressor and the differential gear required are manufactured in India and many developing countries.

PEST-PROOFING EMULSION

The emulsion is based on Lindane and DDT. The solvents, vegetable oil, synergist and emulsifiers are indigenous chemicals. The production of Lindane can be started by the firms which are manufacturing BHC in India. The chemical assays, bioassays and toxicological studies do not indicate any foodgrain contamination hazards, if the bags are treated with the PEST-PROOFING EMULSION by the PEST-PROOFING MACHINE under recommended conditions. Cost of emulsion will not exceed Rs. 50/- per gallon and this can treat 700 bags.

Precautions to be taken:

The insect-proofed grain bags after being filled with grain may be carried by human labourers on bare backs. In such a case, the skin contamination daily of one individual on a long, continuous or repeated contamination of the insecticide may give rise to cumulative toxicity effects in the long run. Therefore, in a godown a labourer should be provided with a plastic coated cloth or polyethylene sheet of enough length to be tied and spread on his back while carrying the insect-proofed bags. This can be washed with soap and water after day's work. However, the labourers are being exposed to the same hazards even to-day due to the large-scale and regular insecticidal dusting programmes in grain godowns in private and Government warehouses. This aspect of the present health hazard should be eliminated as soon as possible.

A private firm may be licensed by the India Government (CSIR Ministry of Commerce and Department of Agriculture) to manufacture the Pest-Proofing Emulsion. The factory and its running should be carried out by a competent chemical firm.

The PEST-PROOFING MACHINE can be manufactured by the firms who are dealing with spraying equipment. No foreign exchange is required except in the mechanisation (i) compressor petrol or powerdriven, (ii) differential gear and motor. These two items can be manufactured by Indian firms.

One thousand (1,000) small firms are to be licensed for carrying out the pest-proofing and Durofume Fumigation Processes at the Regulated Markets, Mandis and Municipal Markets.

Suggested steps for implementation:

1. The regulated market and large village market should have provision for a fumigation room and insect proofing of jute bags within the premises. The standards Institution should include the specifications for suitable structures to be erected in the different market layouts.

2. The Central Marketing and State Marketing Departments should licence contractors for disinfestation treatments of bags and grains within the Regulated Market premises. The charges also should be fixed by the market authorities.

3. The training of the fumigation operators and the technical know-how of the processes can be offered by the Central Food Technological Research Institute (CSIR), Mysore.

4. The issue of licence to the contractors by the Marketing Directorate for disinfestation work in the regulated market should be only on the basis of their employing technical staff who have had proper training at the Central Food Technological Research Institute, Mysore, on these processes developed by the Institute.

5. Introduction of the process in the rural areas through the trained Block Development Officers, Agricultural Extension Officers and Vigyan Mandirs.

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE, MYSORE, INDIA
(Discipline of Infestation Control and Pesticides)

PROPHYLACTIC TREATMENT OF BAG STACKS WITH
DUROBASE SPRAY COMPOSITIONS

For insect free storage of foodstuffs under warehouse conditions any disinfection process should be accompanied by a prophylactic treatment to prevent reinfestation in the fumigated stack. In a godown, the movement of commodities is common. New stacks are built and old stacks are broken for release. Infested materials become the source for further contaminations and infestations. To ensure permanent prophylaxis against insects, the fumigation process should be able to kill all the life stages (egg, larva, pupa and adult) present in all the layers of the bulk commodity, in addition prevention of cross-infestation should be achieved by an insect-proofing process.

Screening of the commonly available fabrics and plastic films used for bagging of cereals and their processed foods have shown that either one or all of the pests such as C.oryzae, S.paniceum, A.fasciculatus, B.chinensis Rhizopertha dominica, Periplaneta americana, Cadra cautella and Corcyra cephalonica were able to penetrate through the packaging materials or lay eggs inside the bags.

TABLE I

Penetration of pests of stored foods through fabrics and films Temp. 22-26°C and R.H. 36-68%

	C.o	T.c.	B.c.	S.p.	R.d	A.f	P.a
Nylon fine mesh	O	O	-	-	A	O	A
Cotton mull	A	-	-	A	A	A O	A
A-twill	O	O	-	-	A	- -	-
Jute A-twill	A O	A O	A O	-	A	A	-
B-twill	A O	A	A O	A O	A	A O	-
D.W.	A O	A	A O	A O	A	A O	-
Heavy cess	A O	A	A O	A O	A	A O	-
Hessian	A O	A	A O	A O	A	A O	-
Polyethylene							
100 g	A O	A O	O	A O	A	O	A
200 g	A O	A	O	A O	A	-	A
300 g	A O	A	-	-	A	-	A
400 g	A O	-	-	-	A	-	A
700 g	- O	-	-	-	-	-	A
Kraft paper	A	A O	-	O	A	-	A
Cellophane	- O	A O	-	O	A	-	A

A=penetrated by adult C.o = Calandra oryzae S.p.=Stegobium paniceum
O= oviposition T.c = Tribolium castaneum R.d=Rhizopertha dominica
- = not infiltrated B.C=Bruchus chinensis a.f=Anastrepha fasciculatus
P:a=Periplaneta americana

Studies carried out showed that insect-proofed jute and other textile bags could be obtained by spraying with o/w (oil in water) type emulsion with a machine containing low volume spray nozzles and having regulated conveyor feeding arrangement for spraying empty bags. As compared to 1.8 kg. the usual water uptake of a standard B-twill bag from an emulsion bath, only 20 gms of water were taken up by 16-18 sq. ft surface of bags in the latter process. Drying of the spray treated bags with the formulation containing DDT and Lindane in the water dispersible formulation was not difficult even in large scale production.

Most often insecticidal treatment of bagged foodstuffs are required during storage in the warehouses of processed food factories. It is difficult to spray the interior of the loaded warehouse with water dispersible composition in view of moisture increase and fungal growth. Dusting with residual pesticidal formulations also cannot be carried out as it presents food contamination hazards. A study was therefore taken up to develop a dry process for a prophylactic spray treatment of the stacks of bagged commodities in situ, with a view to applying it in conjunction with the fumigation treatment. Results of the comparative studies on the persistence and biological efficacies of low viscosity and high viscosity oil based formulations are given in Table 2.

TABLE 2

Effect of carriers on the persistence and insecticidal potencies of BHC, DDT and Malathion

Insecticide	Oil	Persistence on glass	
		'surface after 100 days, g. per sq. ft. (100 mg./sq. ft. applied initially)	LD ₉₅ , mg. per sq. ft., 30 min. exposure* T. castaneum adults
BHC Tech.	Dutrex	60.3	46
	Groundnut	66.2	39
	Castor	63.2	52
	Linseed	68.3	78
	Sesame	67.0	61
	SAE 10	64.5	133
	Batching	62.3	115
	Acetone(control)	33.3	148
DDT	Dutrex	99.0	8.9
	Groundnut	98.3	8.7
	Castor	96.5	9.8
	Linseed	97.2	12.4
	Sesame	98.2	9.4
	SAE 10	95.1	16.6
	Batching	97.2	14.3
	Acetone(control)	89.0	40.1

1	2	3	4
Malathion	Dutrex	21.7	1.9
	Groundnut	29.6	0.8
	Castor	26.4	0.9
	Linseed	29.9	1.8
	Sesame	26.6	2.0
	S.E 10	20.2	2.8
	Batching	22.8	2.2
	acetone(control)	10.4	2.5

* Post exposure incubation 48 hr.

It was observed that groundnut oil and high viscosity mineral oil such as Dutrex and batching oil increased the insecticidal toxicity and stability of the insecticides considerably.

The most commonly used process for disinfection comprises of fumigating the foodgrain bags with EDCT mixture or phostoxin tablets and routine dusting of the bag stack with 5-10% BHC formulation at intervals of 15-21 days. BHC contains in it in addition to the gamma-isomer other components which are not insecticidal but possess chronic toxicity hazard for humans. Infiltration of the residual BHC dust into the grain from the surface of the bags occurs inevitably during repeated applications. By this process the contamination with BHC dust gives rise to cumulative increase on grains, it is therefore, necessary to avoid application of dust formulations and also accumulation of other isomers of BHC than the gamma isomer (Lindane). Very often for good grain storage, fumigation with EDCT or phostoxin should be repeated at 2-3 month-intervals, as internal infestation exists in the stock due to ineffectiveness of these fumigants against pre-adult stages of insects.

It is peremptory that the fumigation process should be able to kill all life stages (egg, larva, pupa and adult) of the pests present in all the layers of the bulk commodity to ensure permanent prophylaxis. Durofume fumigant combination (EDB+MB+Chloropicrin) has been found to be the cheapest and most efficient in disinfecting foodgrains, oilseeds, oilseed cakes, milled products, coffee, dry fruits, macaroni products, and many other commodities.

The prevention of reinfestation (cross-infestation) has been achieved by careful selection of solvents, synergists and pesticides and by adjustments in application of the formulation on the outer surface (periphery) of the stack. Compositions and viscosities of formulations vary according to the stacking materials and commodities stored. Fabrics in gunny bags are A-twill, B-twill, heavy cees, D.W. or Hessian types. A-twill and B-twill sacking materials have smaller pores (weave clearances) and permit direct spraying of a high viscosity oil-based lindane formulation without the risk of contaminating the grain stored in them. The formulation (DUROB-SE-1) is sprayed through

a low volume nozzle at 30-35 lb/sq.in .pressure at the rate of 2 to 2.5 ml per square foot of the bag stack surface. 50 mg of lindane sprayed per square foot in the oil based formulation, Durobase-1, containing a mixture of Dutrex-3, batching oil, linseed oil , ground-nut oil as the carrier, have been found to exert prophylactic action for a period of 4-5 months. Repeated spraying of Durobase-1 at 3 month intervals is enough to keep up the residual action on the fabric surface for preventing cross-infestation. Studies on the assessment of contamination of foodgrains by the droplets infiltrating through the web clearance or other routes by application of this technique have shown safety in this respect (Table -3)

TABLE-3

Lindane infiltration through fabrics (50 mg/sq.ft. initial application on the surface.

Formulation	Viscosity Redwoods No.1(secs).	Drop size. (microne)	Fabrics,mg/sq.ft.			
			A twill	B twill	D.W.	Hessian
1. Kerosine, acetone,xylene.	39	1-60	0	2	6	29
2. Batching oil Dutrex,Ground- nut oil	171	15-320	0	0	1	12

Weave clearance and infiltration time
through fabrics for C.oryzae.

Weave clearance %	3	6	21	68
Infiltration time,mins.	90	45	30	5

The problem was further investigated for storage of grain bags in insect-free condition for periodical release from the treated stack. A formulation based on lindane and malathion should be sprayed from time to time on the wall and around the stacks. If the issue of bags is done from the remotest column of the stack and is followed up by spraying with the Lindane-Malathion oil-based formulation on the exposed surface, it yields excellent result. No liberal spraying is necessary. The sprayed surface should appear dry after spraying. Even a prophylactic spray with pyrethrin and piperonyl butoxide in an oil base, if repeated from time to time as and when new stacks are erected or stacks are disturbed, will give some protection from cross-infestation. But the main drawback of thin volatile mineral oil (e.g. Kerosine, white oil, xylene) based formulation is the contamination to grains. While spraying it gets atomised to very small particles and are drifted into the commodities

through the weave clearance of bags. Moreover, the particle size of droplets being very low the insecticide volatilize very rapidly. The spray loses the insecticidal effectiveness within a few days.

The mineral oils which are thin are absorbed rapidly by grains and also constitute consumer's hazard. Most often it exceeds the permissible limit of 200 ppm. It is for this reason non-volatile high viscosity oil should be used in preference to thin oil formulation under warehouse conditions.

In the case of bags having high weave clearances such as the D.W. and hessian types, direct spraying on the grain bag surface is not desirable. Sacks meant for storage of milled materials also should not be directly sprayed with the insecticidal formulations. Small particles of milled commodities come out of the web clearances and get contaminated and also form a layer over the insecticidal films on the surface of bags. In such cases treated gunny cloth is spread over the bag stack to prevent cross-infestation. Excellent results have been obtained with Durobase-2 treated prophylactic cloth especially in controlling Ephestia sp., on foodgrains and milled products. Durobase-2 formulation containing DDT and BHC should be sprayed on a gunny sheet (prepared by stitching old gunny bags together) at the rate of 2 to 2.5 ml. per sq.ft.

Durobase-2 based on DDT and BHC has proved advantageous under the conditions of use. Durobase-2 when sprayed on gunny cloth remains effective in controlling pests for a period of 10-12 months. Both the pesticides are produced in India.

A new composition has been developed which in addition to its insecticidal action can repel rats. It is interesting to note that malathion which is of low mammalian toxicity and of high toxicity to insects⁵ could exert a high degree of repellent action on rats. This new property of malathion seems to open up excellent possibilities for use of malathion formulation for preventing rodent damage to stored commodities. The results also indicated that with a high viscosity oil the persistence and rodent repellent action of malathion could be prolonged even upto a period of 165 days with a low concentration as that of 20 mg./sq.ft. Table 4.

Highly poisonous chemicals such as barium carbonate, zinc phosphide, red squill, sodium fluoroacetate, alpha-naphthylthiourea, coumarin derivatives, strychnine and thallium salts are in current use for poisoning of rats by baiting techniques. In food storages the risks of contaminating the materials and poisoning of pets and children present very difficult problems for their extensive applications for the control of rats in warehouses and domestic dwellings. This new approach for rodent proofing of stacks and warehouses by spraying insecticidal chemical of low mammalian toxicity at safe levels for human being, to deter the attacks by rats, seems to offer great scope for wide application. This formulation is sold under the name Durobase-3 and based on DDT, Lindane, and Malathion. It is finding extensive application for controlling insects and rodents in storages.

TABLE 4

Effect of carriers on the persistence of malathion and duration of repellency on treated gunny bags.

(Initial concentration of malathion applied 20 mg./sq.ft.)

	Viscosity Redwoods No.1 (Secs.)	Repellency (No. of days)	
		Max.	Min.
Alcohol ..	Below 30	12	7
Kerosene ..	Below 30	17	6
Lubricating oil (SAE-10)	261	19	8
Lubricating oil (SAE-30)	794	26	19
Groundnut oil	240	44	21
Dutrex-3	161	69	42
Dutrex-55	above 2,000	165	88

Dutrex-batching oil used in textile industry (Burmah Shell).

INSTRUCTIONS FOR APPLICATION OF DUROBASE

There are three Durobase Spray Formulations:

- Durobase -1 containing Lindane for short term (3-4 months) effect on bag stacks.
- Durobase -2 containing lindane and DDT for prophylactic treatment of stack and warehouse against insects for 8-10 months.
- Durobase-3 containing Lindane, DDT and Malathion for the insect proofing and rodent-proofing of stacks and warehouses.
- Durobase for Termite Control.

The special features of Durobase formulations are high degree of persistence on treated surface and great toxicity to insects at low dosages of pesticides. Volatile solvents which can be absorbed by grain and give the residue problem as is true with kerosene and volatile solvent carriers in formulations are not present in these formulations. The viscosity of the formulation is extremely important as this governs the efficacy and long term effect. Use appropriate formulation for each problem of infestation control according to the following procedure:

1. Examine the stack, bags and godown to cover all the exposed or spilled grains. The torn bags, may either be replaced with sound bags by replacement or turning sides, or be stitched. Do not spray on exposed grains.

2. Examine the type of bag. If the bags are closely woven, direct spray may be adopted with the DUROBASE. The bags which are not closely woven should not be sprayed directly. Do not spray directly on bags which are containing milled articles (such as wheat flour, atta, semolina and milled articles of other grain). These small particles come out through the weave openings and form coating over the sprayed surface and get contaminated with insecticides. Empty old gunny bags may be opened or hessian cloth and stitched together in the form of a sheet (tarpaulin). Spray the DUROBASE and put it as a cover over the stack (Durobase treated prophylactic gunny cloth.) Standard samples of gunny fabrics will serve as guide, for deciding on the type of spray treatment to be adopted.

3. Use the sprayer with the specified nozzle. Keep the pressure full in the hand compression or the rocker sprayer as low pressure gives coarse spray and wets the fabric. Spray with the recommended pressure to give fine spray at the rate of 12 ml/sq.ft. This level will not wet the bags. It is essential to spray by maintaining high pressure in the SPRAYERS. A pressure gauge may be attached with the sprayer.

4. Calculate the exposed surface area of the stack and transfer measured quantity of DUROBASE in the pump. Bring the pressure full by pumping before releasing the valve of the nozzle. Keep the pressure high by intermittent working of the piston.

5. It is always safe to spray on the bag surface keeping the nozzle axis inclined (at an angle) position than to spray perpendicularly to the surface to be sprayed.

6. In some sample gunny bags, filter paper may be placed below the fabric and the bag stitched with the grain. The filter paper may be examined after spraying for the degree of contamination, if any. These bags may be placed at different positions of the stack.

7. Do not forget to take samples of grains, both before and after the treatments.

8. Markings to detect pilferage and undesirable manipulation of the stack will be advantageous.

9. Take all extra precautions for avoiding contamination of the spray on the grains on body parts and skin.

10. One person in each team should specialise and become skilled DUROBASE SPRAY OPERATOR, who should do the job personally.

11. Smoking and taking food should be avoided during working in godowns. After the work, washing of the protective clothings, hands, etc., with soap and water is essential.

12. Do not transfer the 'Durobase' within the godown because the liquid may be spilled on the floor and material may get soaked in the spilled liquid. Transfer the liquid from containers to sprayer only outside the godown.

13. Do not store the chemicals within a godown containing grain bags. Store away from food articles.

14. Keep watch on the containers - If there is any leakage transfer to a sound container.

DUROBASE SPRAY TREATMENT OF PROPHYLACTIC GUNNY CLOTH

1. Dimensions of the stack:

Length	Ft.
Breadth	Ft.
Height	Ft.

2. Type of sacking:

A-twill
B-twill
Heavy coes
D.W.flour bag fabric

3. Size of gunny cloth:

Length	Ft.
Breadth	Ft.

4. Particulars of sprayer and nozzles used:

- a) Make and type:
- b) Tank capacity:
- c) Lance and hose length and type:
- d) Nozzle type: Swirl
Fan
Low vol.
High vol.

5. Orifice: mm

6. Durobase:	1	Batch	Volume taken in sprayer:	ml.
	2	Batch		
	3	Batch	Volume actually sprayed on each gunny cloth:	ml.

7. Test fabric 6" x 6" piece sample: Identification mark & number: (to be sent to the CFTRI along with the samples of grain, etc. drawn before and after fumigation).

8. Covering of the stack with Durobase treated prophylactic cloth done before or after fumigation.

9. Prophylactic Durobase spray on walls, doors and windows of the warehouse around the treated stack:

Area sprayed:

Nos. of Doors:

No. of windows/ventilators:

Quantity of Durobase-1,2,3 used during last
one year ..(Dates) ..

10. Insepction of the treated wall, and stack:

Living insect present or absent:

Remarks on the general conditions of the treated
warehouse:

11. Any special observation or Remark.

SOME DO'S AND DON'Ts ABOUT SPRAYER USE

1. Read and be sure you understand all instructions. Save the instruction manual which may come with the sprayer. Familiarity with these instructions is essential to an understanding of the operation and care of the sprayer.
2. Take the sprayer apart when it is first received to become familiar with all of its parts and their functions.
3. DO NOT operate the sprayer unless all parts are properly assembled.
4. Clean out the sprayer unless all parts are properly assembled.
5. Check the label of chemical formulations to be used in a particular sprayer to be certain that the chemical will have no adverse effect on any parts. Ask the chemical manufacturer or his technical representative to supply such information if it is not on the package label.
6. DO NOT fill tank more than $\frac{3}{4}$ full. Leave balance of tank for compressed air.
7. DO NOT pump sprayer with short, choppy strokes. Use full, even strokes to get maximum pressure in least time and effort.
8. Clear the hose line of air before spraying to avoid spitting. With pressure in the tank, point the spray extension tube upwards and open the valve. This will release air in the hose and replace it with liquid. Then when you begin to spray, there will be no air bubbles in the line.
9. Check fittings and connections periodically to be certain they are tight and secure. This is especially important before highly toxic or stain-producing chemicals are used.
10. Use goggles or protective lenses when spraying a chemical which may injure eyes.
~~poke at anything with the nozzle. This could cause clog-~~
~~ing or damage.~~
11. DO NOT poke anything into the nozzle orifice. Never use anything stiffer than a bristle or a toothpick to dislodge trapped particles.
12. DO NOT let a sprayer stand for periods of time with chemical in it. Decomposition of the chemical may occur and by-products be formed which may attack the tank or pump. Pinhole leaks may result.
13. DO NOT let the sprayer stand in the sun or other warm place while under pressure. Heat causes pressure to increase.
14. DO NOT try to remove a pump from a sprayer until all pressure has been released. The safest way to open a sprayer under pressure is to release pressure by turning the tank upside down and opening the valve

until all pressure has escaped through the nozzle. Then remove the pump assembly. Another way is to give the top cap just enough of a turn to release air, but not enough to release the cap. Then, after all air has escaped, the pump assembly may be removed. Some sprayers have a separate filler opening and a cover independent of the pump. Turning the handle on the cover of these sprayers $\frac{1}{4}$ turn depresses an air relief valve which permits air to escape from the tank. When all air is exhausted, the tank is opened by removing the cover.

15. DO NOT lay the pump assembly on a dirty surface.

16. Wash out sprayer with water after each day's use.

17. Clean sprayer with a detergent or neutralizing agent once a week.

18. Store sprayer upside down with spray control valve locked open, pump removed and placed in a protected spot. Or, store in a container to keep the hose from being crushed and to protect the nozzle from damage.

19. Oil plunger leather once each week if in constant use. Use only a few drops of clean oil, never heavier than SAE No.30. If leather becomes dry and hard, work oil into leather with fingers. Do not use grease, because this will clog pump check valve.

20. Remove and clean strainers at least once a week, or more frequently if wettable powders are used. Soak in solvent and use a fine brush to remove all sediment.

21. Carry a parts kit in the service truck to handle minor service problems. Keep spares and tools needed for attending to repairs.

22. Be sure to keep a good supply of spare parts on hand.

23. Use care when replacing hose and valve fittings. Use proper size of wrenches on hexagonal fittings to avoid rounding off the face edges. Don't overtighten fittings. Overtightening can strip threads and crush gaskets which can cause leaks, and broken gaskets may clog discharge apparatus. Tighten only enough to insure against leaks. Well-seated gaskets under pressure tend to seal themselves and also prevent leaks.

Replace hose which shows signs of deterioration.

25.

It is better to dismantle wornout sprayers completely and to check carefully what is worth salvaging. Parts which can't be salvaged should be junked at once. Nozzle bodies and valve castings which are not worn might be saved for re-use, but keep salvaged parts separate from new parts, because they will never perform as well as new parts and should not be used where sprayer performance is expected.

BALLOONING TECHNIQUE FOR STORAGE OF MOISTURE SENSITIVE COMMODITIES.

BALLOONING TECHNIQUE

Materials required for Ballooning Technique

- | | | | |
|------|--|-----------------------------------|---------|
| I. | 400 bags or 25 tonnes | (stack size 14.5' x 14.5' x 9.5') | |
| II. | Polyethylene sheets -300 gauge | Size 16' x 16' | 1 No. |
| | | " 35' x 35' | 1 No. |
| III. | Wooden reapers or iron flats | 1" x $\frac{1}{2}$ " x 7.5' | 16 Nos. |
| IV. | 'U' clamps made of M.S. plate 1.5" x 0.25" with 0.5" nuts
screwed at the one limb of the U. The gap between the
two limbs being 2.5" | | 4 doz. |

V. Gunny dunnage Size 16'x16' - 1 No.
or
Hessian Cloth

Hessian Cloth Size 36'x36' - 1 No.

VI. Bees Wax (low grade) 1.0 kg.

Petroleum jelly (white) 0.5 kg.

VII. News paper (old) 5 kg.

VIII. Durobase-3 0.5 to 0.6 gallon

Procedure: i) Estimate the moisture of the commodity, if it is within the safe, moisture level proceed with Ballooning if moisture is beyond the critical level dry the commodity to safe level.

ii) Prepare the dunnage with any of the following: Old discarded gunny bags, newspaper sheets, paper clippings, soft husk, palm matting or metallic sheets.

iii) Spray with Durobase III (a high viscosity oil based insecticidal composition with synergistic action and long persistence on treated surface developed at the Institute) the floor and the surface of the dunnage material at the rate of 2 ml. per sq.ft.

iv) Place 300 gauge polyethylene sheet of size adequate to cover the area on which the material will be stacked. Keep one foot extra sheeting around the occupied area (Stacking area) of the stack. On the polyethylene sheet spread a layer of paper or gunny sheet treated with Durobase III.

v) Build the stack layer by layer (not column by column) starting from one edge. Care should be taken not to trample or stand on the polyethylene sheet with shoe on or any sharp material for avoiding damage by puncture or tear. Place the next row of bags standing on the bag row already laid. Build the full stack and now spread Durobase III treated paper on the top surface of stack. Four hundred bags of 60 kg. each can be stacked in 14' x 14' x 9' and require sheets of 16' x 16' one piece at the bottom and another 35' x 35' sheet as cover.

vi) Draw another polyethylene sheet over the stock and bring the free ends together with the bottom sheet. A cotton tape impregnated with a wax composition containing bees wax and petroleum jelly (100 : 30 parts, having also an insect repellent) is now placed along the margin of the bottom polyethylene sheet. The proportion of petroleum jelly should be reduced at temperatures above 35°C and increased at temperatures below 23°C.

vii) The edges of the top and bottom sheets are brought together and folded neatly. The folded seam is now placed in between two wooden reapers

and clamped. Alternatively, the seams may be weighed down under a batten on the floor.

viii) Now cover the balloon on all sides with a sheet of gunny cloth treated by spraying insecticidal composition Durobase III.

ix) If the commodity ballooned is carrying insect infestation, then disinfest the stock by employing Durofune Process. (The process has been described elsewhere).

Some Special Advantages:

i) The balloon structure can be erected in any place under the existing warehouse conditions without disturbing the method of storage or practice.

ii) No change in the constructional feature of the godown is required.

iii) From the balloon structure the materials can be taken out anytime and released.

iv) The materials used in the ballooning technique can be used year after year.

v) The balloon structure is proof against insects and rodents, and offers a satisfactory barrier for moisture increase or loss of the stored commodity.

Precautions:

i) The polyethylene sheets are to be handled carefully during ballooning and stored properly when not in use.

ii) Commodities should be ballooned with moisture contents below the critical moisture levels.

iii) Trained personnel should apply the process for which facilities are available at the CFTRI, Mysore.

Ballooning - Costing for 400 standard bags
or 25 tonnes, in Rupees (Indian)*

	1st year	2nd year	3rd year	4th year	5th year
1. Polyethylene (250-300 gauge) sheets					
35'x35' = One					
16'x16' = One	90.00	-	-	-	-

7. 1. 1'

7.

	1st yr.	2nd yr.	3rd yr.	4th yr.	5th yr.
2. Wooden Reapers 1"x0.5"x 7.5'=120' R.ft. or flat iron 0.5 x 0.25 x 7.5')	20.00	-	-	-	-
3. U Clamps 4 doz.	10.00	-	-	-	-
4. Hessian cloth 36'x36'-1 17'x17'-1	70.00	-	-	-	-
5. Wax, Petroleum jelly, Durobase, paper etc.	25.00	15.00	15.00	15.00	15.00
6. Labour & miscellaneous	15.00	15.00	15.00	15.00	15.00
	230.00 or 0.57/bag	30.00 or 0.07/bag	25.00 or 0.06/bag	25.00 or 0.06/bag	25.00 or 0.06/bag
7. Depreciation on items 1-5@ 20% ⁺	43.00	43.00	43.00	43.00	43.00
8. Interest 6% on Rs.215/-	12.90	12.90	12.90	12.90	12.90
per tonne Rs.	11.36	3.44	3.44	3.44	3.44
per bag Rs.	0.70	0.22	0.22	0.22	0.22

* Although the costing is based on 400 bags; with the same materials, 500 bags can easily be stored.

+ With skilled operators life can be increased considerably, only minor repairs are necessary.

Further information can be obtained from the following publications:

1. Studies on the storage of coffee beans -II air-tight storage in bags. S.K. Majumder et al Food Science 1961, 10(10), pp. 322-325.
2. Storage of coffee beans-V.Subrahmanyam et al Indian Coffee January 1961, 25, pp. 26-37.
3. Conservation of Foodgrains under commercial conditions with the application of new pesticidal composition - S.K.Majumder. Symposium on Food needs and resources -National Institute of Science Bulletin, 1962, 20, pp. 119-133.
4. Durofume process Project circular No.3 -Contral Food Technological Research Institute, Mysore. 1958.

5. Studies on the storage of coffee beans - IV. Control of Aræcerus fasciculatus(deg) in monsooned coffee and related storage experiments. S.K. Majumder et al, Food Science 1961, 10(10), pp.332-339.
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7. Some aspects of bulk storage of food grains. Majumder, S.K. & Natarajan, C.P. Wld.Rev.Pest Control 1963, 2(2) 25-35.

NV/
7-5-66.

REVIVIFICATION OF EXHAUSTED GAS MASK CANISTERS.

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(Gas masks fitted with canisters are worn by operating personnel to adsorb from inhaled air toxic gases used in fumigation procedures. The canisters, imported at a high price, have a limited life and revivifying them would be profitable. Hence, a method has been developed for reviving exhausted canisters. It consists in first removing the loose moisture from the canisters and then heating them under vacuum to expel adsorbed water and fumigant vapours. Tests on the revived canisters have proved that they are as good as new ones. The method of revivification and the testing procedure are presented.)

Disinfestation of insect-infested materials is carried out with toxic gaseous chemicals and all such situations of fumigation in pest control operations call for the use of gas-masks fitted with recommended type of canisters.¹ These canisters are inlaid with suitable gas-adsorbents which remove the toxic gases from the inspired air and afford protection to the user against volatile toxicants present in the environment. The service life of the canisters in use, however, is limited. It depends on the nature, quantity, concentration and technique of application of the fumigant, the atmospheric temperature and humidity, the volume of breathing and the period of exposure of the operator. Generally speaking, a new canister is effective against less than 2% of the toxicant in air.² At or near this maximum capacity the canister will not afford protection for more than 10 min.³ According to Brown,⁴ intermittent use at low concentrations as obtaining in normal fumigation practice will give a service time of about 2 months. A canister is replaced when the canister log card denotes a cumulative use for 2 hr. When a canister emits slightest foreign odour or when it has been in storage for more than six months, then also it has to be replaced.

At present, canisters required in large scale pest control programmes in our country are imported from abroad. Their limited life added to the prohibitive cost places a heavy burden on our foreign exchange. Hence investigations were undertaken to revive exhausted canisters for reuse and a process has been standardized for the revivification of canisters containing activated charcoal for use against organic fumigants like ethylene dichloride-carbon tetrachloride (EDCT), methyl bromide (MB) and ethylene dibromide (EDB) and mixtures of ethylene dibromide and methyl bromide (EDB-MB).

Revivification

Since canister carbon is known to be hydrophilic,² any process

of revivification should also remove the moisture absorbed in the carbon. Hence the weighed canisters are first scrubbed with hot (50-60°C) dry air at a rate of 1 litre per min. for 6 hrs. to remove loosely-held water and other vapours in the adsorbent until they show constant weights. In the second stage, the tenaciously held water and fumigant vapours are driven off by placing them inside a vacuum oven whose inlet cock is connected with a calcium chloride tower and silica gel column and heating for two successive periods of 2 hr. at 100°C and 130°C under a pressure of 4 mm. Hg. The canisters are then cooled to room temperature (25-28°C) in the oven at the same pressure and then atmospheric pressure is restored in the oven by admitting dry air into it through a column of activated silica gel. The canisters are immediately sealed with the nipple cork and the baseplate and weighed. The whole process is repeated until the weight of each canister is constant thereby indicating that the moisture and the organic vapours are distilled off.

Testing revived canisters

The service time of the canister is tested in a testing assembly (Fig.1). The procedure for testing with methyl bromide is as follows.

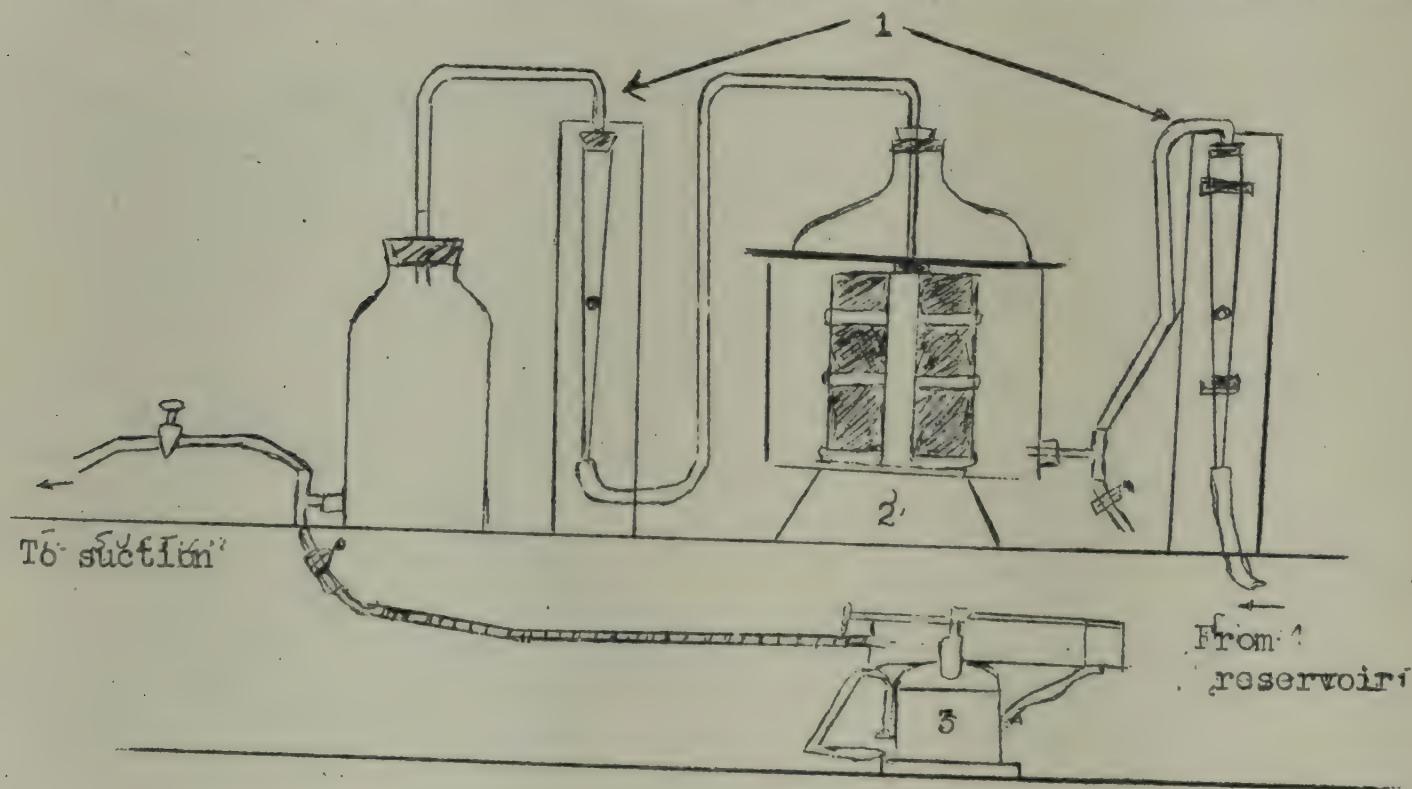


Fig.1:- CANISTER SERVICE TIME TESTING ASSEMBLY

A mixture of 2 per cent by volume of methyl bromide (72 g. methyl bromide per cubic meter of air at 25°C and 696.5 mm. Hg) checked by a Riken interferometer is metered (1) from a reservoir through the canister placed in a 16.6 litre desiccator (2) at a rate of 32 litres per min. (equivalent to the breathing of a man walking at the rate of 3½ m.p.h.⁵). At the end of each minute of flow, signs of break-through (exhaustion of the canister), are tested with a sensitive 'Tilley' halide lamp burning methyl alcohol (3). The flame of the lamp is adjusted to be intense green even 17 ppm. (the permissible limit

of methyl bromide in air for prolonged exposure).

In a similar testing procedure with EDCT, revived canisters gave service times as good as that of new ones (Table I) while unrevived canisters gave less than 3 min. Actual man test has also been carried

Table I - Efficiency of revived gas mask canisters

Canister markings	Quantity of carbon (ml.)	Service time* (min.)	
		MB	EDCT
Puretha Type 'O' (New canister)	1500	13	-
Puretha Type 'O'	1500	11	63
Puretha Type 'O'	1500	12	66
M.S.A. 33-05	725	8	48
M.S.A. 33-21	725	13	78
M.S.A. 33-21	725	13	78
Drager	650	6	36
Drager (New canister)	650	5	34

MB, methyl bromide; EDCT, Ethylene dichloride-carbon-tetrachloride (3:1)

*Measured against 2% (MB = 4.5 lb./1000 cu.ft;
EDCT = 5.1 lb./1000 cu.ft.)

out with the revived canisters in practical fumigation, results of which also showed that exhausted canisters could be effectively revived by the process described. Some typical data on the fumigant adsorption and service times of the revived canisters as well as new ones are presented in Table I.

While choosing a fumigant for general use the operational cost, the expense on importation of the canisters and fumigants should be considered with due emphasis on efficiency and economy. For instance the EDCT mixture, a fumigant composition of low toxicity to insects now being used extensively requires repeated fumigations with high doses (35 lb./1000 cu.ft.) for ensuring insect mortality in food-grain stocks. The high dosage used reduces the canister life in view of the low permissible concentration⁶ in the atmosphere, i.e., 25 ppm. Use of efficient low dosage fumigants such as ethylene dibromide and methyl bromide would save not only the expenditure on importation of new canisters but also increase the service life of the canister, with reduced fumigation costs per unit weight of the commodity treated.

A canister with a service life of 20-30 min. usually costs a foreign exchange of Rs.40/- whereas revivification will cost within

three rupees per canister. Some canisters which have been revived thrice have been found to perform satisfactorily in the man tests during fumigations. Hence adoption of this process of revivification by the industry to supply revived canisters to the servicing firms, warehousing corporations, cooperative societies, and Plant Protection Directorates and Food Departments of the Central and State Governments will save considerable foreign exchange.

References:

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GENERAL NOTE

The service life of gas-mask canisters, it may be noted that after revivification the life will be as much as that of a fresh gas-mask canister. It will, therefore, depend on the type and size of canister, the quantity of adsorbent, etc. If the canisters are exposed to a flow of 2 per cent concentration of methyl bromide continuously at the normal breathing rate then the service life will be as follows:

Purotha	... 15 minutes
MSA	... 13 minutes
Dragger	... 6 minutes
Gaspro	... 3-5 minutes

2. Usually during fumigation with tubing system under gas-proof sheet the concentration of the gas in the atmosphere may not be so high. It is, therefore, the total quantity of gas which can be adsorbed by the canister will be extended over the intermittent periods. The cumulative dosages thus received during intermittent exposures to different gas concentrations during fumigations will determine the time of exhaustion. The gas-mask canisters kept without use goes on adsorbing the traces of organic vapours which may be present in the atmosphere. Thus in a period of 6 months the new gas-mask canisters, even without use will, get de-activated. It is, therefore, very important to keep the gas-mask canister under hermetic condition to avoid the adsorption of the gases from the atmosphere.

3. In view of the important of the 2% gas concentration in the

atmosphere as the maximum limit for the efficacy of the adsorbent of the gas-mask canisters during the usual respiratory intake, exposure to atmospheres containing higher concentrations of the gases should be avoided. The corresponding concentrations to 2 per cent Volume/Volume for MB and EDCT are 4.5 lbs/1000 cu.ft. (72 mg./litre) and 5 lbs/1000 cu.ft. (80 mg./litre) respectively. It is, therefore, evident that the service life of gas-mask canister during usual fumigation with EDCT is much less than that for fumigation with MB. Number of fumigations to be carried out with MB will be much more than that of EDCT mixture. With EDB and MB mixtures, because of the low dosages and modification of the physical properties the service life of the canisters will be more than that of MB alone. In other words number of fumigations which can be carried out with the same canister with EDB-MB mixtures will be more than that of MB fumigation. Until now we have revived the exhausted gas-mask canisters three times without any appreciable loss in their efficiencies.

MR/-

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HYDROLYSIS OF ETHYLENE DIBROMIDE BY MONOETHANOLAMINE
AT ORDINARY TEMPERATURES

M. Muthu & S.K. Majumder

(Central Food Technological Research Institute, Mysore)

Monoethanolamine hydrolysis of ethylene dibromide in gaseous phase has been studied at different temperatures (21-38°C.). Ethylene dibromide undergoes complete hydrolysis within 3, 2, 1 and 0.5 hr at 21.1°, 25-0°, 31-0° and 37.8°C respectively. The method is useful for the assay of ethylene dibromide from fumigation chambers.

RAUSCHER¹, WHILE EXPERIMENTING ON THE USE OF monoethanolamine for the hydrolysis of aliphatic and aromatic halogen compounds, reported complete hydrolysis of the halogen compounds in 49 cases. Hydrolysis of methyl bromide by monoethanolamine even at room temperature was employed by Stenger *et al.*² for the estimation of the fumigant. However, while subjecting ethylene dibromide to hydrolysis by monoethanolamine, at room temperatures low recoveries were obtained by Sinclair and Crandall³. They demonstrated complete dehydrobromination at 90°C. The resulting inorganic bromide was estimated by Volhard's method (Hillebrand and Lundell⁴).

With the increasing importance of ethylene dibromide as a tropical fumigant for grains, fruits and vegetables⁵⁻⁷, the need for the development of simplified methods for routine assay of the fumigant has become imperative. In the present investigation the studies on the monoethanolamine dehydrobromination at various temperatures were carried out with a view to developing a simplified technique for the assay of ethylene dibromide during routine fumigation operations.

In preliminary experiments carried out in this laboratory on the assay of ethylene dibromide samples from a fumigation chamber, it was observed that it is possible to estimate the halogen compound almost quantitatively by carrying out hydrolysis of the fumigant by monoethanolamine even at room temperatures. A detailed study of hydrolysis of ethylene dibromide by monoethanolamine at various temperatures was, therefore, undertaken.

Thin-walled glass ampoules containing 1 ml. of monoethanolamine (E. Merck) were placed in iodine flasks (250 ml.) and ethylene dibromide (E. Merck) pipetted into it. The flasks were stoppered and weighed before and after adding the fumigant. Sufficient time was allowed for the fumigant to volatilize before releasing monoethanolamine by breaking the ampoules. The flasks were swirled vigorously to distribute monoethanolamine uniformly on the walls of the flasks. After the reaction period, inorganic bromide formed was estimated by Volhard's method and calculated for ethylene dibromide.

The iodine flasks containing the fumigant in the gaseous phase were subjected to hydrolysis at 21.1°, 25-29° (room temperature), 31.0° and 37.8°C. for 24 hr. The mean percentage of ethylene

dibromide estimated as a result of hydrolysis at these temperatures was not significant. In a second experiment, the gas samples drawn from an all-glass fumigation chamber in 100 ml. sampling flasks were hydrolysed at room temperature for 24 hr and in another set at 90°C. for 30 min. in a hot-air oven³. The results obtained showed that the amount of ethylene dibromide accounted for in the sample was the same by both the methods. The difference in the values for ethylene dibromide in the samples by the two methods was 0.54 ± 0.46 , which was not statistically significant (Table 1).

To determine the threshold time required for the complete hydrolysis of ethylene dibromide at various temperatures, ethylene dibromide in the gas phase and monoethanolamine were allowed to react at 21.1°, 25.0°, 31.0° and 37.8°C. for 30 min., 1, 2, 3, 4,, 5, 6, and 8 hr. The results are graphically recorded in Fig. 1. The reaction was complete within 3, 2, 1 and 0.5 hr at 21.1°, 25.0°, 31.0° and 37.8°C. respectively. These results are contrary to the observations of Sinclair and Grandall⁵.

The results of the present study indicate the possibility of utilizing monoethanolamine hydrolysis for determining ethylene dibromide concentrations in commercial fumatoria and warehouses during fumigation operations. The following procedure was followed. A two-way gas sampling flask (100 ml.) containing a 1-ml. ampoule of monoethanolamine was connected to the sampling line from a 200 cu. ft fumigation chamber and the gas was aspirated using a 1 litre capacity aspirator connected to the shorter limb of the sampling flask (Fig. 2). The aspirator was run till a certain representative sample of the gas had been drawn. Then the stopcocks on the sampling tube were closed and the flask shaken to break the monoethanolamine ampoule. The tube was kept in the open sun after distributing monoethanolamine well on to the walls of the tube. After 1 hr exposure to the sun, the resulting inorganic bromide was estimated by Volhard's method. The results show that the method is quite reliable and can be used for routine fumigant assay in godowns.

TABLE 1- ESTIMATION OF ETHYLENE DIBROMIDE
FROM FUMIGATION CHAMBER

Theoretical conc. mg./litre	Found	
	mg./litre	%
1	2	3
Reaction at 23-0°C. for 24 hr		
96.00	90.40	94.47
82.18	59	72.99
78.73	66	83.98
79.69	64	81.10
112.00	68	78.90

(Contd.)

1	2	3
Reaction at 90°C. for 30 min.		
95.37	89.56	93.90
81.26	58.08	71.47
77.91	64.44	82.71
75.36	60.74	80.60
111.21	70.17	63.10
		Mean 78.36

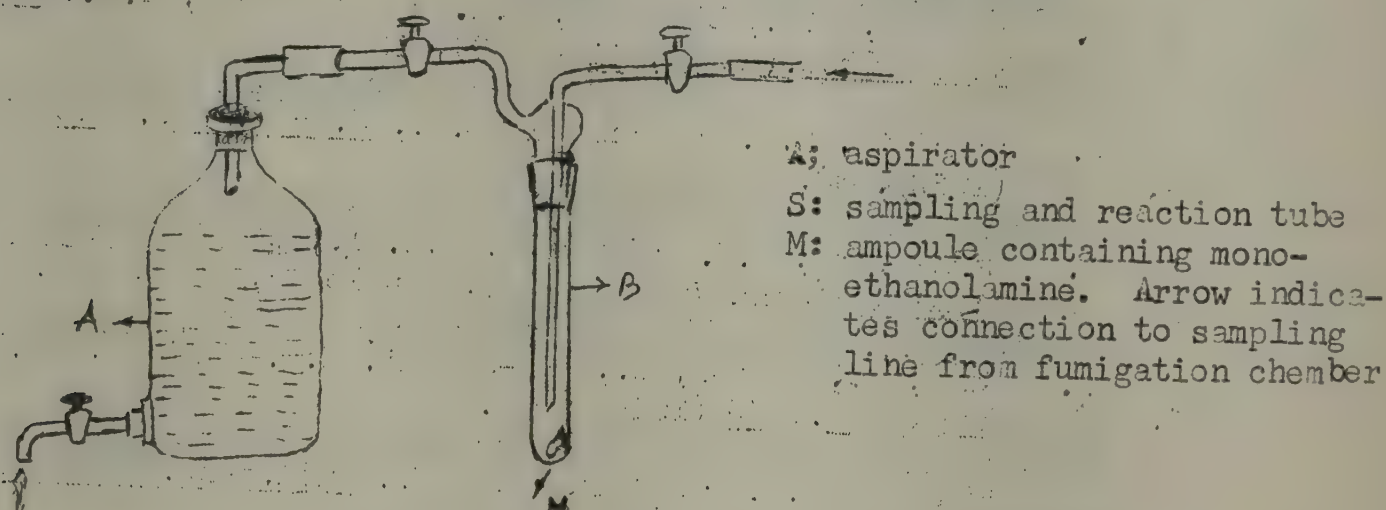


Fig. 2- Assembly for gas sampling.

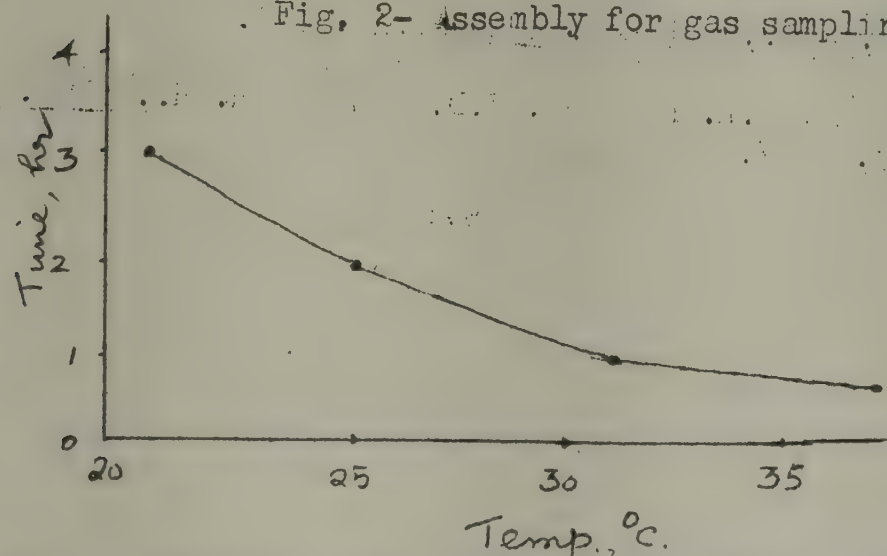


Fig: 1-Threshold time required for complete hydrolysis of ethylene dibromide at different temperatures.

By adopting this technique, evacuated flasks, vacuum pump, high temperatures and the necessary appliances required in the current method³ were avoided, and the fumigant concentration could be determined in the warehouses during normal fumigation work. Due to the high price and non-availability of rapid gas analysers in India, such as the thermal conductivity units⁸, this simplified technique of analysis at ordinary temperatures will prove advantageous for routine assay.

A portable fumigant analytical kit is being designed based on the above work, the constructional details and working of which will be described elsewhere.

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CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE, MYSORE
(S.K. Majumder, T.S. Krishnamurthy & M. Muthu)

AN INFRA-RED HEAT DISINFESTATION UNIT FOR FOODSTUFFS

Disinfestation of milled and whole grains has been studied employing infra-red heat treatment of the materials and a time-temperature product of 600° Centigrade-minute standardized as the optimum requirement for the purpose. A continuous heat disinfestation unit has been designed using a battery of infra-red bulbs to heat up a rotating stainless steel tube through which the material is fed. The optimum conditions for efficient heat disinfestation of groundnut, jowar, Bengal gram dhal, cotton-seed and Indian multipurpose food are reported.

Infra-red heating possesses many advantages over conventional methods of heating such as speed of operation, simplicity of oven construction, flexibility of control, instant starting and stopping facilities and low initial and operating cost.

Many of the food commodities cannot be fumigated with the commonly available fumigants in view of large residues and toxic reaction products left on the foodstuffs by the chemicals. Repeated fumigations may also be needed in these materials for insect control which may lead to the concentration of the residues beyond the permissible levels. Disinfestation of food grains by heat treatment has been studied in the past and attempts have been made for developing a suitable equipment for the purpose¹⁻⁵. Earlier work⁶ in this laboratory on the heat disinfestation of spice powders has shown that disinfestation of Stegobium panecium could be obtained by spinning cans filled to 60 per cent capacity and exposing them to a steam temperature of 92-93° at 250 r.p.m. for 5 min. in a spin pasteurizer. This equipment is only suitable for materials packed in cans and not for grains and other milled materials in bulk. In the present investigations, disinfestation of commodities such as jowar, wheat, cottonseed, pulses and dhals, milled materials like semolina and Indian multipurpose food has been carried out employing infra-red heat treatment and a unit for continuous disinfestation has been designed.

The materials were infested by their respective insect pests and were assessed for complete lethality of all the life stages by exposing them to infra-red irradiation for different periods using 150 W. infra-red lamps (Infraphil of Philips (India) Ltd.,). A time-temperature product of 600° Centigrade-minute was required for mortality of all the stages of Tribolium castaneum, Sitophilus oryzae, Bruchus chinensis, Araecerus fasciculatus and Stegobium panecium. The threshold temperature for short exposure of infested material was recorded at 58° C.

Since infra-red heating due to its special, characteristics⁷ was

found to be very promising for treatment of infested commodities with reference to heating and achievement of lethal temperature for all the stages of the insects within comparatively short period of exposure⁸, an equipment was designed for continuous heat disinfection of grains and their milled materials.

The equipment:

The equipment (Fig.1) essentially consists of a thermally insulated cylindrical chamber in which one internally polished metal tube (diam. 12 cm., wall 18-24 gauge, length 3 m.) is mounted coaxially. The top of the chamber is fitted with a battery of 10 infra-red bulbs of 150 W. capacity each. The heat treatment tube is exposed to the irradiation of the lamps. Rotation of the tube about its axis is effected by a mechanical unit comprising an adjustable reduction gear powered with a 0.5 h.p. motor. The heating chamber is fitted with thermocouple junctions at the hopper end, middle and tail ends and also inside the heat treatment tube near the discharge end. The thermocouples are connected to a multiple junction pyrometer for indicating the temperatures directly.

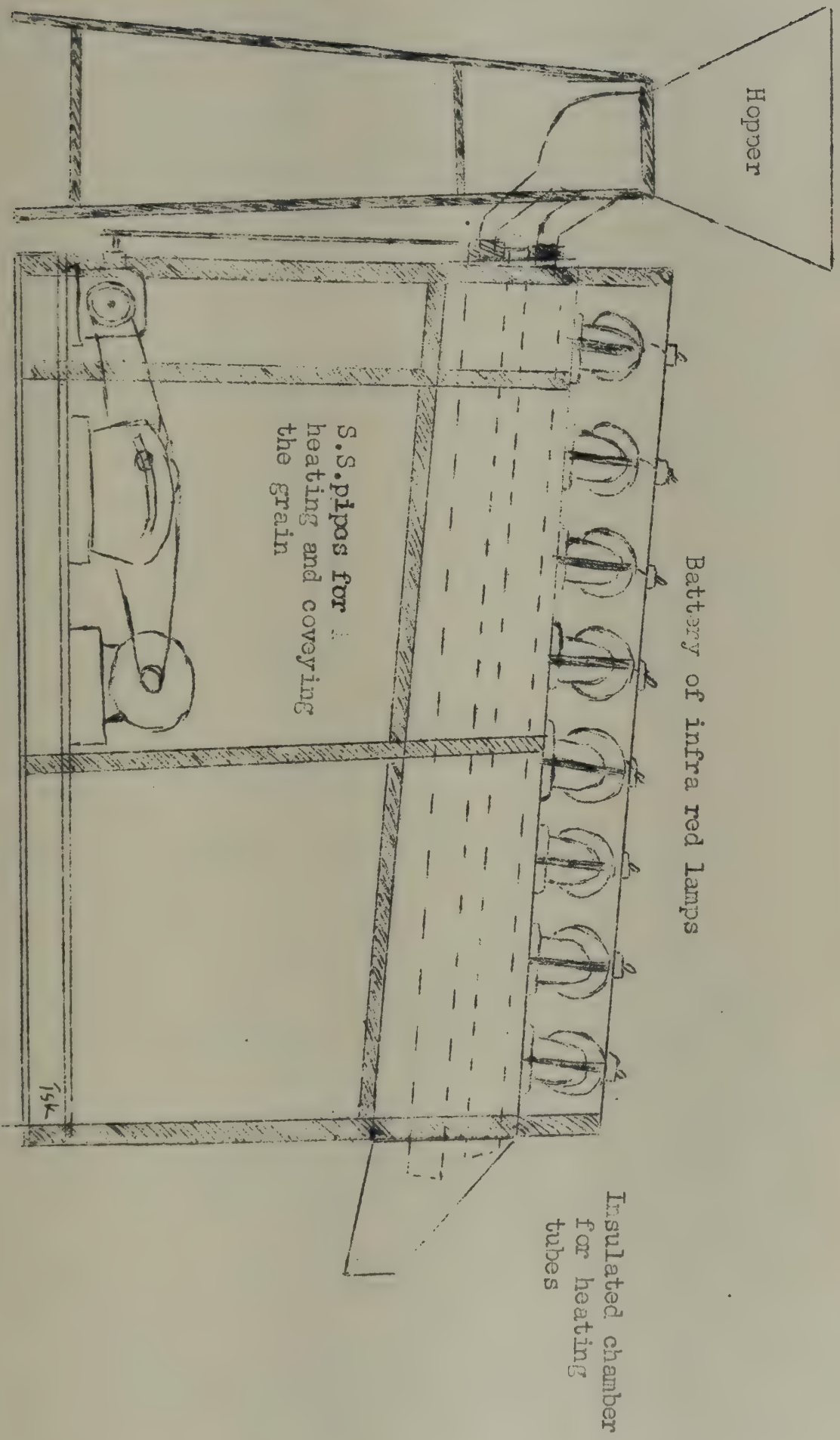
Material is fed through the hopper by gravity and it gets gyrated through the heated pipe. It was observed that the temperature of the chamber has to be maintained at 110-121°C. between the ends. For each commodity, the time of travel through the heated tube was determined for attaining a temperature of at least 60° C. at the time of discharge. The time of travel could be adjusted by manipulating the inclination of the tube in conjunction with the speed of rotation. The data obtained for efficient disinfection of certain commodities are given in Table 1.

The effect of temperature may be prolonged in the receiver receptacles by keeping them insulated during the cooling process, so as to obtain an increased lethal time-temperature product and also to avoid sweating or moisture condensation. After cooling the material, it could be mixed well by agitation to equate the moisture gradient that might have been created due to condensation during cooling.

Table 1 - Optimum conditions for infra-red heat disinfection of foodstuffs

Commodity	Angle of inclination of heating tube to horizontal (deg.)	Rotation of heating tube r.p.m.	Temperature of material at feeding end °C	Temperature of material at discharge end °C	Time of travel min.	Weight of material treated/HR kg.
Groundnut seed	3	35	43	65	1.5	88
Jowar	5	40	45	68	2.0	56
Bengal gram dhal	5	45	43	65	2.0	61
Cottonseed	5	45	45	65	1.5	64
Multipurpose food	7	60	45	68	2.5	37

INFRA RED HEAT DISINFESTATION UNIT



Heating of commodities can be carried out in a coke oven, or room heater or the electric roasters of the type used for roasting coffee beans and the like. Oil-fired burners and steam-jacketed drums have also been used for drying of different commodities in processing lines. The unit developed would be less cumbersome to install and repair and consumes less power than a heating coil. Infra-red heating possesses many advantages over conventional methods of heating such as speed of operation, simplicity of the oven construction, flexibility of control, instant starting and stopping facilities and low initial and operating cost. Direct heating with the infra-red was found to be wasteful and insufficient to achieve disinfestation quickly in the bulk of the material. Heat transfer was quicker when the grain was in contact with the heated metal surface than direct exposure to the radiation of the infrared lamps. The metal surface heated by the infra-red lamps would also give more uniform heat to the materials in contact as the material spirals down the inclined plane. Naked insects and their eggs in the materials would also get a high temperature contact from the metal surface, almost akin to a flash pasteurization unit.

The capacity and efficiency of this pilot scale unit could be improved by assembling a battery of tubes geared to each other in a bigger tunnel fixed with the infra-red lamps. This would ensure commercial requirements for rapid heat disinfestation of large quantities of materials.

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SERIAL FUMIGATION OF PROCESSED AND PACKAGED FOODS WITH AIR-
WASHED RESIDUAL METHYL BROMIDE FROM FUMIGATION CHAMBERS.

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(Manuscript received January 27, 1961)

SUMMARY:

The possibility of using residual methyl bromide left after exposure in fumatoria for more fumigations in subsequent fumatoria was demonstrated. Use of the air-washing technique to obtain more fumigant concentration in the atmosphere of the next fumatorium in the series proved advantageous. In the 24-hours exposure series, the residual concentrations in air were low because of prolonged sorption by the commodities, so not more than two fumigations could be attempted, whereas in the varied-exposure series 3 fumigations could be attempted with the initial dose of 32 mg/L, stretching over an integrated exposure period of 27 hr with 100% mortalities of the test insects.

METHYL BROMIDE is finding increasing application as a fumigant of stored products since its first use, in France, by Le Goupil(1932). Brown (1959) and Cotton (1958) enumerated its manifold advantages over other fumigants, such as high toxicity to insects at low doses and short exposures, high penetrability into commodities, low residues, quick aeration, and lack of fire hazard.

Among the various techniques of fumigation with methyl bromide, some form of vacuum fumigation (Brown, 1958) is the obvious choice for quarantine and food processing and packing establishments, where time, ease of handling, and safety are major factors to be considered. Economy in any phase of operation would be welcome.

In a preliminary assessment at the Institute of fumigation with methyl bromide, considerable amounts of post-exposure fumigant were held in the atmosphere of the fumigation chambers. A survey of the post-exposure concentrations of methyl bromide in warehouses and fumatoria was therefore carried out. The results are in Table 1. The data show the air concentrations of methyl bromide under various conditions of fumigation. These indicated the possibility of using this residual fumigant for further use. It appeared possible if the concentration-time (CT) product required for mortality of insect pests could be achieved (Brown, 1959). This could be achieved either by increasing exposure time or by replenishing the fumigant to the required level. In vacuum techniques, the practice of "air-washing" also contributes to this spent fumigant, and at reduced pressures the release of residual fumigant absorbed by the materials is also fairly high (Brown, 1958). Investigations of the above thesis form the subject of this paper.

EXPERIMENTAL

Fumatoria: The first set of experiments was carried out in 11-L-capacity (inclusive of the lid) vacuum desiccators fitted with two capillary stopcocks, one just reaching the bottom but not touching it, and the other opening $\frac{1}{2}$ in. below the stopper. The second set of fumigations were done in 50-L mild steel cylinders provided with three sampling points, with capillary stopcocks at the top, middle, and bottom positions (Fig.1). A vacuum line provided with gauges was connected to the serial fumigation battery.

Dose of fumigant: Methyl bromide containing 2% chloropicrin (May & Baker, Ltd., Bombay) was used in all the trials. The conventional dose for vacuum fumigation used by several workers varies between 30-60 mg/L, depending on the material, temperature, package, infestation, and hours of exposure (cotton, 1956; Monro and King, 1954). In the present study a working dose of 32 mg/L was employed for assessing the applicability of the residual fumigant for serial fumigations.

Table 1. Space concentrations of methyl bromide (MB) under various fumigation conditions.

Fumatorium and load	Dose applied (mg/L) ¹	of	Exposure (hr)	Free space (Mg/L)	Gas loss ¹ (%) and reuse possibility ²
1	2	3	4	5	6
Desiccator					
Tapioca macaroni ³					
in 250-gauge sealed polyethylene bag	33.0	86.0	18	29.0	3.0Y
	37.0	36.0	24	31.0	10.0Y
MPF ⁴ (unseasoned)	48.0		24	1.0	98.0N
MPF (seasoned)	48.0	77	48	1.4	97.0N
Spices	32.0		48	31.27	0.1Y
Autoclave					
MPF	32.0	79.86	18	8.5	73.0Y
Wheat, Jowar & rice	32.0	77	24	20.5	35.9Y
MPF	32.0		48	3.0	91.0N
Wheat macaroni	32.0	75.0	24	11.0	67.0Y
Cashew nuts	32.0		48	0.5	98.0N
Mild steel cylinder					
Jowar	32.0	82.85	24	11.0	67.0Y
Wheat semolina	48.0	75.77	24	26.0	46.0Y

1	2	3	4	5	6
Aluminum vault					
Macaroni (21 cases)					
and groundnut flour					
(2 bags)	59.0	89.0	43	20.0	66.0Y
Macaroni (19 cases)					
in heat-sealed					
polyethylene bags	56.0	83.87	43	30.0	46.0Y
PVC Fabric tent					
Wheat semolina (9 bags)	64.0		48	38.0	41.0Y
Terraced brick &					
mortar ⁵					
Pulses (900 bags)	9.0	77.79	96	5.0	37.5Y
Pulses (350 bags)	16.0		120	1.0	94 N
Pulses (174 bags)	16.0		120	10.5	34Y
Pulses (631 bags)	15.0		48	1.0	94N

- 1 Methyl bromide losses through sorption, leakage, etc.
- 2 Y, yes; N, no.
- 3 60 parts tapioca, 25 parts wheat semolina, 15 parts groundnut cake flour (5-6% oil).
4. Multi-purpose food: 75 parts defatted groundnut flour; 25 parts roasted Bengal gram flour; fortified with vitamins and minerals. Seasoned MPF has added spices and salt.
- 5 These fumigations were carried out with 1:1 (w/w) mixture of ethylene dibromide and methyl bromide. The values given here are expressed as methyl bromide.

Technique of fumigation:

The first fumatoria in the series were evacuated. The fumigant as a liquid was measured with a microburette into a two-way stainless-steel applicator in a refrigerated room maintained at 10°F, brought to room temperature, and administered at the top position of the fumatorium under partial vacuum. Atmospheric pressure was restored by flushing air through the two-way fumigant applicator by the technique described by Brown and Houser (1953a). The exposure period was 24 hr in the constant exposure series, whereas in the varied-exposure series the fumigation period ended when the mortality of the test insect was noted (Table 3). The knockdown effects were characterized by their falling on their backs, immobility of appendages, and absence of any response to light stimulus.

At the end of the exposure periods, all the second fumatoria in the series were evacuated to 10 mm absolute and the vacuum broken by sucking the fumigant-air mixture from the bottom portion of the first fumatoria. It was similar to the air-washing process described by several workers (Brown, 1958; Brown and Heuser, 1953b; Monro and King, 1954), except

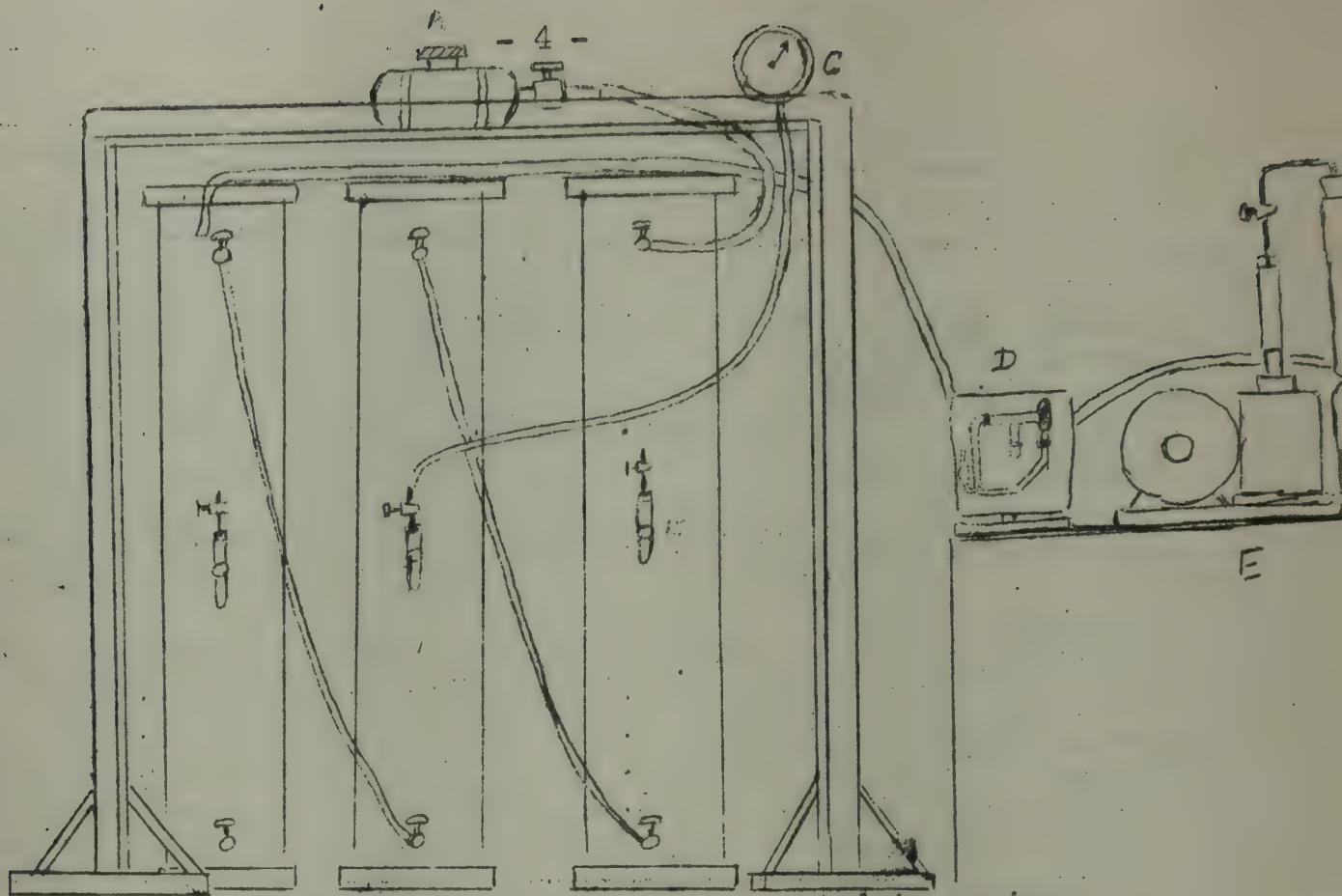


Fig. 1. Fumigation columns connected in series.
 A) fumigant applicator; B) insect exposure tubes; C) vacuum gauge; D) McLeod gauge; E) vacuum pump.

that the residual fumigant was flushed into the next fumatorium for further use instead of being expelled to the atmosphere. The subsequent fumatoria were similarly air-washed after each exposure into the next in the series until sufficient fumigant concentrations were available.

Table 3. Fumigation in loaded fumatoria. (Initial concentration of methyl bromide (MB) applied: 32 mg/L.)

Fumatorium & load	No.fumi-Ex-gations in series	Ex-posure (hr)	MB conc. at end of exposure (mg/L)	Residual MB after air-washing (mg/L)	Cumulative % loss of MB over the nominal conc.	Mortality of test insects (%)
1	2	3	4	5	6	7
<u>Glass:</u> Dry fruits & nuts in polyethylene bags.	1	24	24.5	8.0	23.4	100
	2	24	12.2	5.3	61.9	100
	3	24	4.7	0.0	85.3	100
Macaroni, rice (no packing)	1	24	17.1	6.2	46.6	100
	2	24	4.2	2.1	86.9	100
	3	24	0.7	0.0	97.7	100
						(48 hours)
<u>Mild steel:</u>						
Processed foods in polyethylene bags held in deal wood boxes.	1	24	11.1	6.7	65.3	100
	2	24	3.2	1.3	77.2	100
	3	24	1.5	0.0	95.3	5.3

1	2	3	4	5	6	7
50 lb. of tapioca macaroni rice packed in	1	3.0	16.4	11.2	48.7	100
200-gauge polyethylene bags.	2	6.0	7.5	2.6	76.4	100
	3	18.0	2.3	0.0	92.7	100

Test insects:- *Tribolium castaneum* (Hbst.) adults about 3-4 weeks old, reared on wheat semolina at 80°F and 68% RH, were used as test insects. Mortalities of test insects could be noted in the case of glass desiccators but not in mild steel fumatoria. Hence the test insects were placed in glass insect exposure tubes and left in communication with the fumatoria during treatment (Fig.1). This provided a satisfactory "window" for observation.

Analyses:- Gas samples were drawn at the culmination of each exposure period by the evacuated flask method and analyzed by the method of Stenger et al. (1939), monoethanolamine being the dehalogenating agent. The availability of fumigant from the fumatorium for reuse after the exposure period was assessed.

The fumigation operations, gas analyses, and mortality counts of test insects were carried out in both empty and loaded fumatoria at room temperature ($25 \pm 1^\circ\text{C}$), with three replicates in each test. The load, different types of infested food materials carrying adults and immature stages of insects (Table 2), filled 4/5 of the space in the fumatoria. The mortality counts in the commodities were made 4 days after fumigation, and the samples were kept for incubation at 31°C and 70% RH to assess the mortality of immature stages. The fumigant residues in the samples (Table 4) were determined by the method of Young et al. (1943).

Table 2. Commodities and insect infestation.

	Insect species
Dry fruits and nuts	<i>Oryzaephilus surinamensis</i> L.
Almonds (shelled)	<i>Ephestia cautella</i> Wlk.
Apricots	<i>O.surninamensis</i>
Cashew kernels	<i>O.surninamensis</i>
	<i>Tribolium castaneum</i> Herbst.
	<i>Ephestia cautella</i> Wlk.
Dates (dessert variety)	<i>O.surninamensis</i>
Figs (dried)	<i>O.surninamensis</i>
Dates (dried)	<i>O.surninamensis</i>
	<i>T.castaneum</i>
Groundnut kernels	<i>O.surninamensis</i>
	<i>T.castaneum</i>
	<i>E.cautella</i>

Insect species	
Pistachio (shelled)	O.surninamensis O.surninamensis
Processed foods	
Biscuits (Britannia: arrowroot)	O.surninamensis T.castaneum
Biscuits (Nutro, based on MPF)	O.surninamensis
Corn flakes	O.surninamensis
Macaroni (tapioca)	Calandra oryzae L.
Macaroni (wheat)	T.castaneum
Multipurpose food (seasoned)	T.castaneum
C.F.T.R.I.	E.cautella
Multipurpose food (unseasoned)	Stegobium paniceum L.
C.F.T.R.I.	
Prawn (dried)	Dermestes sp.
Wheat semolina	T.castaneum Carpophilus hemipterus L.

RESULTS AND DISCUSSION

Fig. 2 shows the residual methyl bromide concentrations in glass and metal fumatoria at the end of the exposure periods in each serial fumigation attempted.

The data showed that, in empty glass desiccators, the airwashed residual fumigant could be re-employed for five more fumigations after the initial fumigation at 32 mg/L. Death of some *T.castaneum* adults was obtained in even the fifth transfer. The concentration fell to 2.7 mg/L and 4.5 mg/L in the constant and varied exposure batches, respectively, at the end of sixth fumigation. Sorption of the fumigant on the wall was comparatively greater in empty metal cylinders and 5 serial fumigations could be attempted with benefit. The concentration of methyl bromide in the final fumigation was 3.1 mg/L and 4 mg/L in the constant and varied exposure batches, respectively, which did not warrant further use. The loss from sorption on the wall of the fumatorium would have reduced the concentration in air below the level required for mortality of the test insects.

With load (Table 3) in the 24-hour exposure series in desiccators the residual fumigant could be circulated only twice again, making a total of 3 fumigations with a starting nominal dose of 32 mg/L. A load of macaroni rice was found to sorb more fumigant than a load of dry fruits and nuts, and the exposure had to be prolonged to 48 hours in the third transfer to get the required CT product for a 100% mortality of *Calandra oryzae* (Brown, 1959) adults.

In metal fumatoria with a load of processed cereal foods, groundnut kernels and raisins in heat-sealed 200-gauge polyethylene bags packed in dealwood cases (to simulate commercial packaging) there was a very

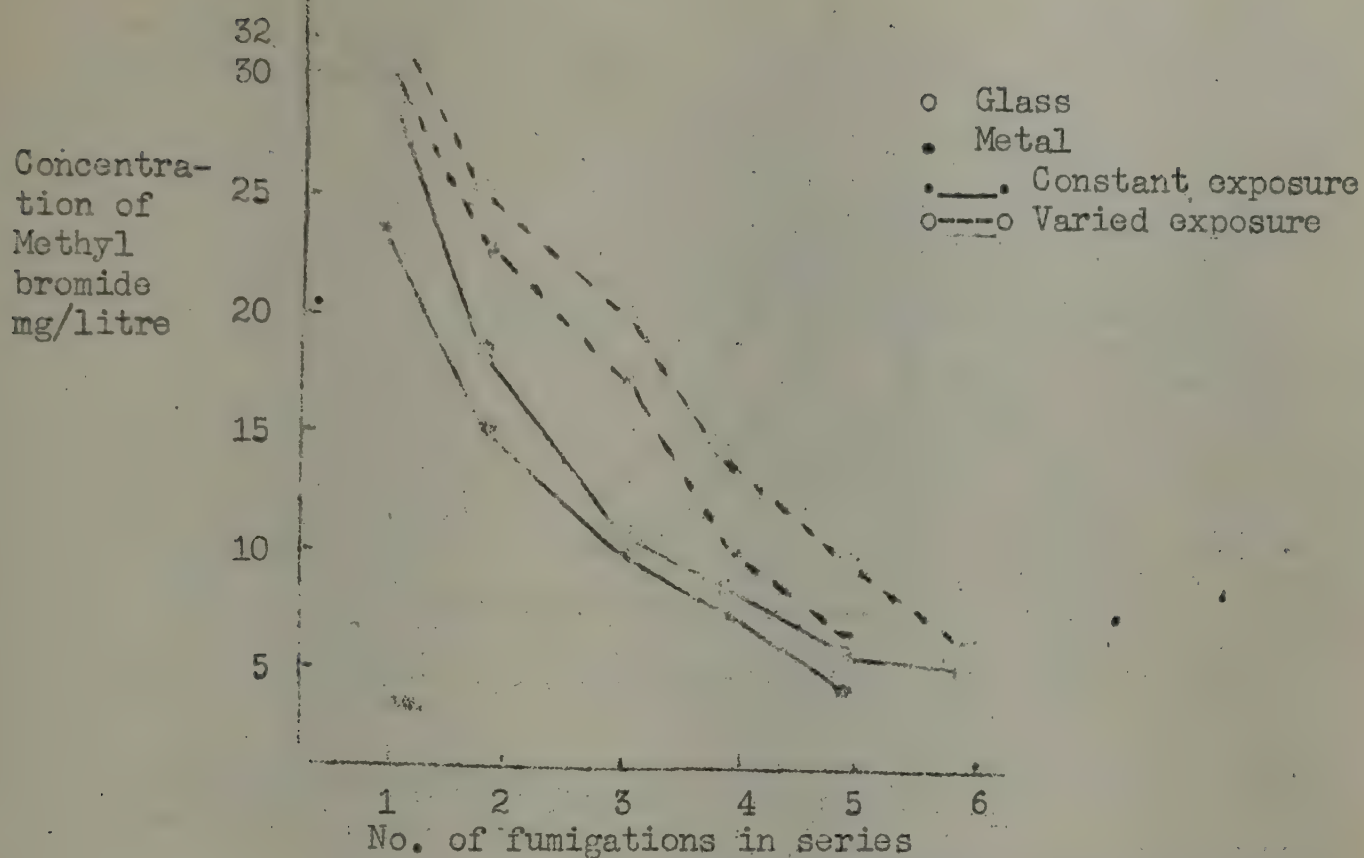


Fig. 2. Residual fumigant concentrations after each exposure in glass and metal fumatoria.

serious depletion of methyl bromide concentration in the 3rd fumigation in the series. The insect mortality was incomplete because of a lowered CT product. Brown (1959) reported: "For practical purposes, it seems to be unimportant whether these values (lethal concentration-time products) are obtained by a high concentration for a short time or a lower concentration for a correspondingly longer time so long as the concentration is greater than 2 mg/Litre. There is some evidence that, at very low concentrations of 2 mg per litre or less, these CT products would not be sufficient."

The shorter exposure periods, on the other hand, not only gave the required CT product but also provided enough residual fumigant in the atmosphere for reuse (Fig.3, Table) in three successive fumigations.

In the test with loaded fumatoria consisting of 50 lb. of tapioca macaroni rice packed in heat-sealed 200-gauge polyethylene bags, 3 fumigations could be attempted with the starting concentrations of 32 mg/L (based on empty vault volume), getting 100% mortality of the test insects (*C.oryzae* and *T.castaneum*) throughout. The residual concentrations of methyl bromide in the air samples of the first fumatoria were quite high (Table 3), even after air-washing and transferring to the second fumatoria in the serial fumigation batteries. The reason was progressive release of the sorbed fumigant by the commodities. This observation has also been reported by other workers (Brown and Heuser, 1953b). However, in spite of these cumulative losses to sorption by the load of the sequential fumatoria, reuse value was demonstrated for further fumigation of the residual fumigant after the exposure period under the conditions of the technique. In a tall column during the exposure period, methyl

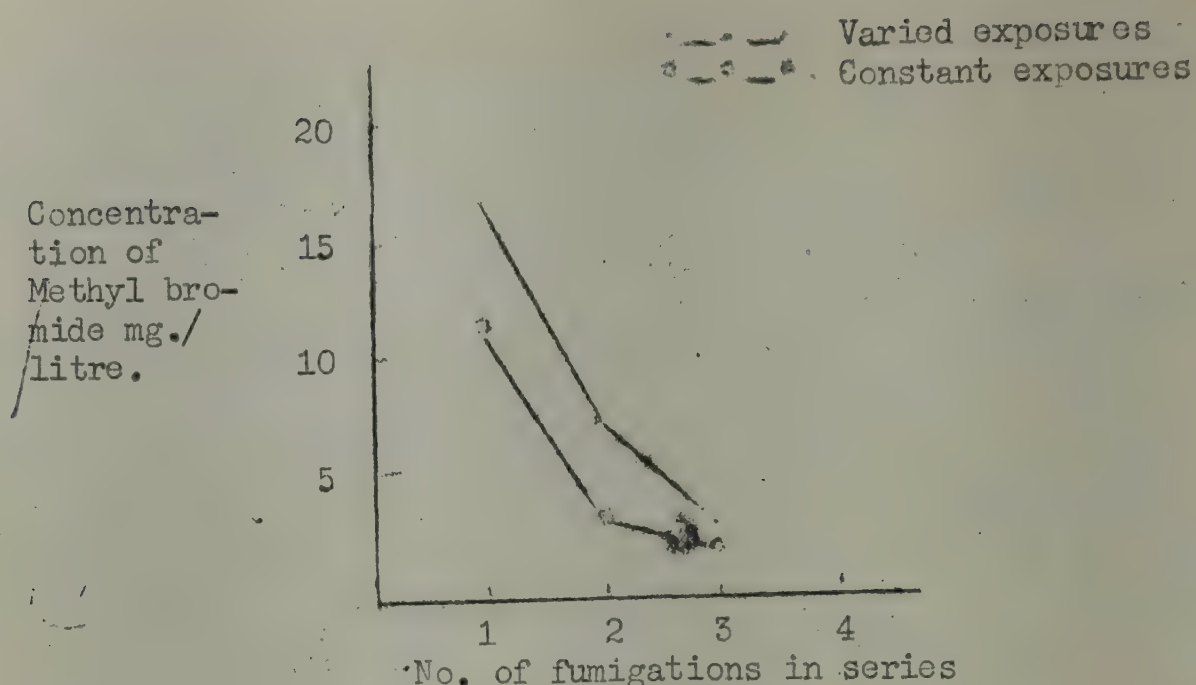


Fig. 3. Residual fumigant concentrations after each exposure in metal fumatoria with load.

bromide descends toward the bottom in the absence of a circulatory system; it is therefore advantageous to suck the fumigant-air mixture from the bottom portion of the fumatorium into the 2nd fumatorium in the series, as described. As air is sucked from the top portion to restore the atmospheric pressure during the air-washing of the fumigated cylinder, more and more fumigant is drained into the subsequent fumatorium.

Bromide residues in the commodities:- The values given in Table 4 represent the average of three determinations. There was steady reduction in the residue values as the methyl bromide concentrations registered progressive reduction in the serial fumigations. Cashew kernels and pistachio showed high residues, and dried prawns also gave a high figure (84 ppm). The reaction of methyl bromide with the proteins of the prawn, and the fat and proteins of cashew kernels and pistachio may be responsible for high bromide residues resulting from the fumigation. This aspect needs further study.

CONCLUSIONS

In the fumigation technique reported, air-washing employed by the vacuum fumigation installation has been used with better advantage by utilizing the same processes for removal as well as transfer of the residual fumigant for subsequent fumigations in the series. If a quicker treatment is necessary, only the depleted level of the fumigant need be added for bringing economy in the use of the fumigant. A pilot-scale installation for adopting the serial fumigation technique is shown in Fig. 4. This was used with all the advantages described in the paper. The closed system in which the serial vacuum fumigations are done introduces the safety factor of handling methyl bromide

1
Table 4. Bromide residues (ppm) on materials treated with methyl bromide in the serial fumigation technique

Commodity	I Fumigation (Initial)	II Fumigation (Transfer-1)	III Fumigation (Transfer-2)
Dry fruits and nuts:			
Almonds (shelled)	22.0	14.0	9.1
Apricots (dried)	7.0	4.0	1.0
Cashew kernels (raw)	255.0	133.0	103.0
Dates (dessert)	7.0	4.0	2.0
Dates (dried)	11.0	7.0	4.0
Figs (dried)	16.0	11.0	2.0
Pistachio	136.0	65.0	39.0
Raisins	6.0	3.0	2.0
Groundnut kernels (with cuticle)	23.0	11.0	12.0
Processed foods:			
Biscuits (arrowroot)	25.00	6.0	4.0
Biscuits (Nutro) (CFTRI) ²	19.0	16.0	12.0
Corn flakes	19.0	8.0	3.0
Macaroni (wheat) (CFTRI)	6.0	5.0	4.0
Macaroni (tapioca) (CFTRI)	6.0	4.0	3.0
MPF (Unseasoned) (CFTRI)	15.0	6.0	5.0
MPF (seasoned) (CFTRI)	36.0	19.0	9.0
Wheat semolina	29.0	8.0	6.0
Prawns (dried)	84.0	28.0	4.0
Tapioca macaroni in polyethylene ³	6.5	3.9	2.6

1. Total bromide after deducting corresponding control values.
2. Central Food Technological Research Institute,
3. Varied exposures; all others were constant exposures.

bromide without being exposed to the noxious gas. The economy on the use of canisters, which are expensive, can be effected by the adoption of the technique. By the time the series is completed, the fumigant concentration in air will be quite negligible and aeration will not be a serious problem. The usual taint in materials, such as cashew nuts ordinarily fumigated with methyl bromide, was not so apparent in the samples treated by the serial fumigation technique. Air-washings probably play a part in removing the characteristic volatile fumigant reaction products constituting the odor (Winteringham et al., 1955). This aspect is being studied in detail. The bromide residues were well within the permissible safe limits prescribed in the U.S.A. and Canada (Majumder, 1960).

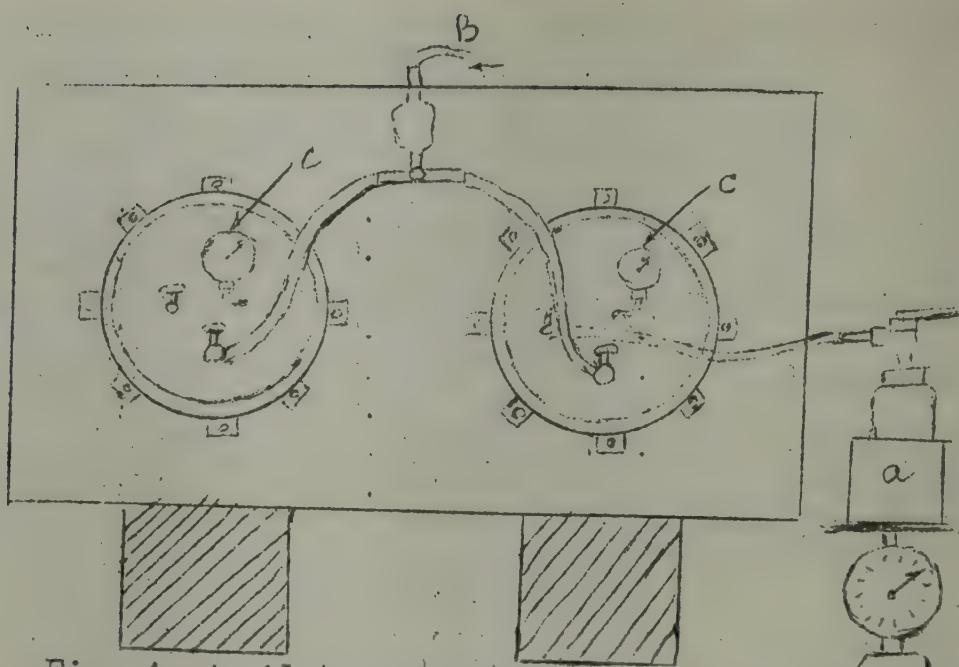


Fig. 4. A pilot-scale installation depicting serial fumigation.
(a) gas cylinder; B) suction line with silica-gel absorber; C) vacuum gauges.

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MALATHION AS A REPELLENT FOR RATS

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In spite of the tremendous losses caused by rats to stored commodities throughout the world and the intensive investigations in evolving safe and economic methods for their control, no specific poison or repellent has been discovered for practical application. Rodenticides which are in current usage have high order of toxicity also to man.¹ Researches on insect proofing of jute bags and other bulk packages have led to the development of pesticidal compositions suitable for practical application especially for preventing re-infestation from outside sources.^{2,3} Although, the insecticides have been successfully used for preventing the cross-infestation of stored commodities by the insects, the deterrence or repellency of these insecticidal chemicals to rodent attacks have not been evaluated. Twenty-seven pesticidal solutions were, therefore, tested by impregnating sacklets containing rat baits for their repellency or otherwise to Rattus rattus.

Out of the chemicals tested, eugenol and malathion (S (1-2 dicarbethoxyethyl) O, O-dimethyl dithiophosphate) showed high degree of repellency to Rattus rattus. A protective action from rodent attack could be exerted for a period of even more than 20 days with a concentration of 20 mg./sq.ft. of malathion on the bag surface. As malathion was found to be possessing high degree of repellency to rats and also could control insect infestation, the persistence of malathion on gunny sacklet when sprayed with different carriers was studied.

In this experiment, malathion was carried in different carriers (Table I) and the viscosities of the formulations were determined with Redwood's viscometer. Standard size jute bags were sprayed at the rate of 20 mg./sq.ft. area with malathion. Number of days of protection from rodent attack offered by different formulations of malathion were recorded and the concentrations of malathion were estimated by the method of Norris et al.⁴ The data are presented in Table I.

It is interesting to note that malathion which is of low mammalian toxicity and of high toxicity to insects⁵ could exert a high degree of repellent action on rats. This new property of malathion seems to open up excellent possibilities for use of malathion formulation for preventing rodent damage to stored commodities. The results also indicated that with a high viscosity oil the persistence and rodent repellent action of malathion could be prolonged even upto a period of 165 days with a low concentration as that of 20 mg./sq.ft.

Highly poisonous chemicals such as barium carbonate, zinc

TABLE I

Effect of carriers on the persistence of malathion and duration of repellency on treated gunny bags

(Initial concentration of malathion applied 20 mg./sq.ft.)

			Viscosity Redwoods No. 1 (Secs.)		Repellency (No.of days)		Malathion (% retention after 90 days)	
				Max.	Min.	Max.	Min.	
Alcohol	..	Below 30		12	7	0	..	
Kerosene	..	Below 30		17	6	0	..	
Lubricating oil (SAE-10)		261		19	8	0	..	
Lubricating oil(SAE-30)		794		26	19	10	9	
Groundnut oil	..	240		44	21	28	22	
Dutrex-3	..	161		69	42	48	34	
Dutrex-55	Above	2,000		165	88	57	42	

Dutrex-batching oil used in textile industry (Burmah Shell).

phosphide, red squill, sodium fluoroacetate, alpha-naphthylthiourea, coumarin derivatives, strychnine and thallium salts are in current use for poisoning of rats by baiting techniques.¹ In food storages the risks of contaminating the materials and poisoning of pets and children present very difficult problems for their extensive applications for the control of rats in warehouses and domestic dwellings. This new approach for rodent-proofing of stacks and warehouses by spraying insecticidal chemical of low mammalian toxicity at safe levels for human being, to deter the attacks by rats, seems to offer great scope for wide application.

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Characteristics of some major pests of stored foods

COLEOPTERA (Beetles and Weevils)

1. Sitophilus oryza L. Rice weevil

or

Calandra oryzae L. -do-

Sitophilus granarius L.

Calandra granarium L. Granary weevil

Destructive phases: Adult and larval stages

Adults: Very active, live for four to five months in winter.

Egg: 250 per single individual, 3-6 days

Larva: Very active, three to four weeks

Pupa: 4-8 days. Life History: 4-6 weeks.

2. Rhizopertha dominica F. Lesser grain borer

Destructive phases: Adult and larval stages.

Adults: Good flier, mild activity, comparatively short lived

Eggs: 300-500 per individual, 4-6 days

Larva: Internal feeder, 35-45 days

Pupa: Internal, 7-8 days. Life History: 6-8 weeks

3. Trogoderma granaria Everts. Khapra beetle

Destructive phases: Larval stage

Adult: Very mild and short lived

Egg: 120-135 per individual, 6-20 days

Larva: Duration varies considerably, 4 weeks to 2 years

Pupa: 6-10 days. Life History: 6 weeks to 4 years.

4. Tribolium castaneum Herbst. Rust Red flour beetle

Tribolium confusum Duv. Confused flour beetle

Destructive phases: Adults and larval stages.

Adult: Very active, 6-10 months

Egg: 400-450 per individual, 5-12 days

Larva: Very active, 4-12 weeks

Pupa: 6-9 days. Life History: 4-12 weeks.

55. Oryzaephilus surinamensis L. - Saw toothed grain beetle.

Destructive phases: Adult and Larval stages

Adult: Very active, 6-10 months
Egg: 50-300 per individual, 3-6 days
Larva: Very active, 3-10 weeks
Pupa: 8-25 days. Life History: 3-40 weeks

6. Tenebroides mauritanicus L. - Cadelle or yellow meal worm.

Destructive phases: Adult and Larval stages.

Adult: Very active, 2-14 months
Egg: 500-1200 per individual, 2-4 weeks
Larva: Largest of the grain infesting insects, 10-20 months
Pupa: 8-12 days. Life History: 40-160 weeks

7. Stegobium panicum L. - Spice beetle

Destructive phases: Adult and Larval stages.

Adult: Short lived, good flier
Egg: 100-125 per individual, 4-8 days
Larva: Internal breeder in whole grains, builds cocoons in flour
Pupa: 6-10 days. Life History: 6-10 weeks.

8. Lasioderma serricorne F. - Cigarette beetle.

9. Laemophloeus minutus Oliv. - Flat grain beetle

Adult: Very small and active, unable to attack sound grain
Egg: 125 per individual, 4-8 days
Larva: Very active, 2-4 weeks
Pupa: Pupates in cocoon, made out of fine material. Life History: 4-6 weeks.

10. Alphitobius piceus Oliv. - Fungus beetle.

Destructive phases: Adult and Larval stages.

Adult: Very active, 6-14 months
Egg: 200-400 per individual, 4-12 days
Larva: As big as that of caddie, 10-120 weeks.
Pupa: 8-15 days. Life History: 12-40 weeks.

11. Brachymeria fasciculatus de Geer. - Coffee bean weevil.

Destructive phase: - Larvae

Adult: Good flier, short lived
Egg: 150-200 per individual, 3-9 days
Larvae: Internal breeder, 45-60 days
Pupa: Internal, 6-8 days. Life History: 47-135 days.

12. Callosobruchus chinensis L. - Pulse beetle

Destructive phase: Larva

Adult: Good flier, short lived

Egg: 150-200 per individual, 3-8 days

Larva: Internal breeder, 20-40 days

Pupa: Internal, 6-8 days. Life History: 3-8 weeks.

LEPIDOPTERA (Moths)

1. Sitotroga cerealella Oliv.

Destructive phase: Larva

Adult: Good flier, short lived, 1-2 weeks

Egg: 120-400 per individual, 5-7 days

Larva: Internal breeding, 2-3 weeks

Pupa: Inside the grain in a silken cocoon, 4-6 days.

Life History: 4-6 weeks

2. Plodia interpunctella Hubn. - Indian meal moth

Destructive phase: Larva

Adult: Good flier, short lived, 4-15 days

Egg: 30-350 eggs per individual, 2-15 days

Larva: Construct tunnels and live inside, 30-35 days

Pupa: Pupates inside the tunnel, 4-35 days, Life History:
4-40 weeks.

3. Ephestia cautella Walker. Almond moth

Destructive phase: Larva

Adult: Very active, 8-12 days.

Egg: 200-250 per individual

Larva: 40-50 days. Prepares silken tubes in which they live.

Pupa: Inside the silken cocoon, 8-12 days. Life History:
6-8 weeks.

4. Corcyra cephalopica Staint. Rice moth

Destructive phase: Larva

Adult: Very active, 8-15 days

Egg: 90-200 per individual, 3-5 days.

Larva: 20-35 days. Mature larvae lives in tough silken cocoon.

Pupa: Pupates inside silken cocoon, 8-10 days. Life History.

Scientific name	Common name	Commodities commonly attacked
1. <u>Sitophilus oryza</u> L.	Rice weevil	Wheat, rice, jowar, corn, macaroni, synthetic rice, tapioca chips etc.
2. <u>Rhizopertha dominica</u> F.	Lesser grain borer	Broken cereals, wheat, rice, sorghum, pulses, corn products, macaroni, etc.
3. <u>Trogoderma granaria</u> Everts.	Khapra beetle	Broken cereals, wheat, barley, malt foods, dhal (split pulses) soji and broken pulses.
4. <u>Tribolium castaneum</u> Herbist	Rust red flour beetle	Milled materials of cereals, pulses and oil seeds, processed foods and confectionery
5. <u>Oryzaephilus surinamensis</u> L	Saw toothed grain beetle	Oil seeds, dry fruits, confectionery, fruit candy, maida, nuts, flour, oilseed cakes.
6. <u>Terebroides mauritanicus</u> L	Cadelle or yellow meal worm	Cereals-wheat, sorghum and rice
7. <u>Stegobium paniceum</u> L.	Spice beetle (orient) Biscuit beetle (continent) Drug-store beetle (West)	Spices, confectionery, processed foods and drugs.
8. <u>Lasioderma serricornis</u> F.	Cigarette beetle	Tobacco, processed leaves, cigarettes, cigars, variety of spices and drugs.
9. <u>Laemophloeus minutus</u> Olive	Flat grain beetle	Broken grain, cereals, pulses, oil seeds and deteriorating processed foods.
10. <u>Brachocerus fasciculatus</u> de Geer.	Coffee bean weevil	Coffee, stored cocoa bean, arecanuts, tapioca chips, banana chips, cotton seeds and leguminous seeds with high moisture content.
11. <u>Callosobruchus chinensis</u> L.	Pulse beetle	Stored whole pulses, Bengal gram, green gram, field beans, other legumrs,
12. <u>Sitotroga cerealella</u> Oliv	Paddy moth or Tropical warehouse moth	Paddy, sorghum (Ears) in fields.

Scientific name	Common name	Commodities commonly attacked
13. <u>Plodia interpunctella</u> . Hubn.	Indian meal moth	Food grains.
14. <u>Ephestia cautella</u> Walker	Almond moth	Oil seeds, currants, raisins, dried apples, Berries, figs, almonds, walnuts, pistachio, chocolates, biscuits, tamarind seeds, garlic, broken cereals and broken pulses.
15. <u>Corcyra cephalonica</u>	Rice moth	Rice, other broken cereals, oil seeds and processed foods.
16. <u>Alphitobius piceus</u> olive	Black fungus beetle	Mouldy food stuffs.
17. <u>Latheticus oryzae</u> (Waterh)	Long headed flour beetle	Wheat, rice, corn, barley, rye, flour, dried vegetable material.
18. <u>Attagenus piceus</u> (oliv)	Black carpet beetle	Jute bags, fibres, foods stored in gunny bags, carpets and wooden material.
19. <u>Carpophilus dimidiatus</u> F.	Corn sap beetle	Botting and decaying fruits, and vegetation, damp and decaying grains, in rice mills.
20. <u>Gibbium psylloides</u> Fab.P.	Hump beetle	Cereal cakes, yeast, wheat, dry bread, cotton seeds, pay paste and paprika.
21. <u>Caryeodon gonagra</u>	Groundnut bores	Uncorticated nuts, legume seeds.
22. <u>Alasverus advena</u> (Waltl)	Foreign grain borer	Damp grain and seeds.
23. <u>Necrobia rufipes</u>	Red-legged ham beetle	Dried fish, copra, coconut cakes.
24. <u>Calandra linearis</u>	Tamarind weevil	Tamarind seeds and legume pods.
25. <u>Sitophilus Zea-maia</u>	Corn weevil	Rice, sorghum, corn.

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE, MYSORE

SOME USEFUL CONSTANTS

GENERAL

Inch = 25.4 millimetres (m.m.)
Foot = 0.305 metres (1)
Yard = 0.914 metres = 36 inches
m.m. = 0.039 inch
Meter = 39.37 inches
Meter = 1.094 yards

Sq. inch = 6.452 sq. cms
Sq. ft = 144 sq. inches
Sq. cm. = 0.155 sq. in.
100 Mesh = 149 Millimicron; 325 mesh = 44 millimicron
Acre = 0.405 hectare
Acre = 660x66=43560 sq.ft.

Cu.inch = 16.387 cu.cms.
Cu.ft = 0.028 cu.meter
Cu.ft = 28.317 litres
Imp.Gallon = 4.543 litres
Cu.Meter = 35.314 Cu.ft.
Litre = 61.023 Cu.inches
Litre = 0.220 Imp.gallon
Bushel = 35.238 litres or 1.2444 cu.ft.

Ounce (oz) = 28.349 gms.
1 fluid ounce = 29.574 ml
Lb. = 0.454 kg.
Ton = 1016 kgs.
Kg. = 2.205 lbs.
Ton(Metric) = 2205 lbs. or 1000 kg.
Maund = 37.324 or 82.11 lbs.

Atmospheric pressure 14.7 lbs/Sq in or
at sea level 760 mm Hg.

For every 1000 ft elevation decreases by 0.5 pounds

Converting Centigrade to Fahrenheit:

$$^{\circ}\text{F} = 1.8^{\circ}\text{C} + 32$$

$$\text{Converting Fahrenheit: } ^{\circ}\text{C} = \frac{{}^{\circ}\text{F} - 32}{1.8}$$

Velocity 1 m.ph = 88 ft/min = 1.467 ft/Sec.

" 5 m.p.h = 440 ft./min = 7.33 ft/Sec.

" 10 m.p. = 880 ft/min = 14.67 ft/Sec.

B. Th. U = 1052 Watt-Sec.

Joule = 0.74 ft-lb

" = 778 ft.-lb.

Calorie = 3.968 B.Th.U.

" = 0.252 kg-cal

H.P. = 0.746 K.W.

K.W. = 1.34 H.P.

" = 3415 B. Th.U/Hr

FUMIGANTS

1 lb/1000 cu ft = 16 mg/litre=16 g/Cu.meters=
16 ounce/1000 Cu.ft.

Vapour press. at boiling point = 760 mm Hg.

Vapour press. at melting point = 0 mm Hg. below 1 mm Hg.

Mol.weight (in g.) of gas at N.T.P.

occupies 22.4 litres.

1000 cu.ft. = 803.57 bushels 200 bags (A-twill, B-twill,
D.W. 100 kg bags) occupy 1000 cu. ft.

Each bag = 5 cu.ft.(Approx.)

Floor space for 1 metric ton bag pile 6 sq. ft.

Parts per million (p.p.m.)	$\frac{24,450 \times \text{mg/l}}{\text{mol.wt.}}$
of a fumigant	=
1 ml/litre	= 1 ppm.
1% by vol.	= 10,000 ppm

Saturation concentration above boiling point=

$$\frac{\text{M.W.} \times 1000}{22.4} \times \frac{273}{293} \text{ mg/l}$$

$$\text{below b.p.} = \frac{\text{m.w.} \times \text{v.p.}}{18.6} \text{ mg/l}$$

PESTICIDES

$$\text{Stokes law } V = \frac{2}{9} \frac{r^2 (P-P')g}{n}$$

$g = 981 \text{ cm/sec.}$

V= velocity r=radius

P= density of continuous phase

P'=density of dispersed phase

n= viscosity of air or continuous phase.

Coarse spray	400	μ	and above
Fine spray	100	"	"
Mist	50	"	"
aerosol	0.1	"	"

Diam'φ
(water)

Terminal velocity
cm/min

1	
5	0.18
10	4.5
20	18
100	72
500	1800
	10800

Abbotts formula for corrected mortality

$\frac{x-y}{x} \times 100$, where x = % survival in untreated control
 y = % survival in the treated sample

contract angle	coverage
0°	∞
1°	16
10°	3.8
45°	1.32

spraying 4 lit/Acre

10 diam.gives 1780 droplets/Sq.mm.
 100 diam.gives 1.78 droplets/Sq.m.m.

Viscosity:	Redwoods No.1 (Secs)
Dutrex-3	161
Jute Batching oil	81
Groundnut oil	243
Linseed oil	400
Sesame	220
Kerosene	below 30
S.E-10	89
S.E-90	421

Grain Storage

Grain: thermal conductivity 0.0003 Cgs
 specific heat 0.4
 Thermal diffusibility 0.000115

Sun's rays

Infra red 30-40%
 Wave length 0.28/h-0.92/h
 Radiation 2.0 cal/Sq.cm/min.

	lb/ft ³	φ deg	Coeff.friction
Barley	38.4	26.8	0.507
Corn	47.0	27	0.510
Sorghum	46.4	29	-
Pea	50	25.1	0.472
Rice	36	35	0.700
Wheat	50	25	0.51

Maximum vertical load for rice pile = 0.25/t/sq.ft.
 Intergranular space in bulk
 of total volume = 30%

Perepheral bags in a stack =33%
1000 cu.ft. of volume are occupied by 200 bags.
Surface exposed about 500 Sq.ft./200 bag stack

Each gunny bag = 18 sq. ft. surface
Volume of each standard gunny bag (3.75' x 2.75') on
loading occupies 4.5 Cu.ft.
Weight of (empty) A-twill = 1 kg.

Equilibrium moisture contents of grains
at 28°C (per cent)

	R.H.	30%	50%	70%
Rice		9.0	10.6	12.6
Wheat		8.6	10.5	13.2
Sorghum		8.9	11.0	13.6
Bengalgram		5.1	9.6	14.0
Peanut(groundnut)				
kernel		3.0	4.8	6.6
Cashew kernel		3.1	4.5	6.1
Cumin		9.9	11.4	16.9

